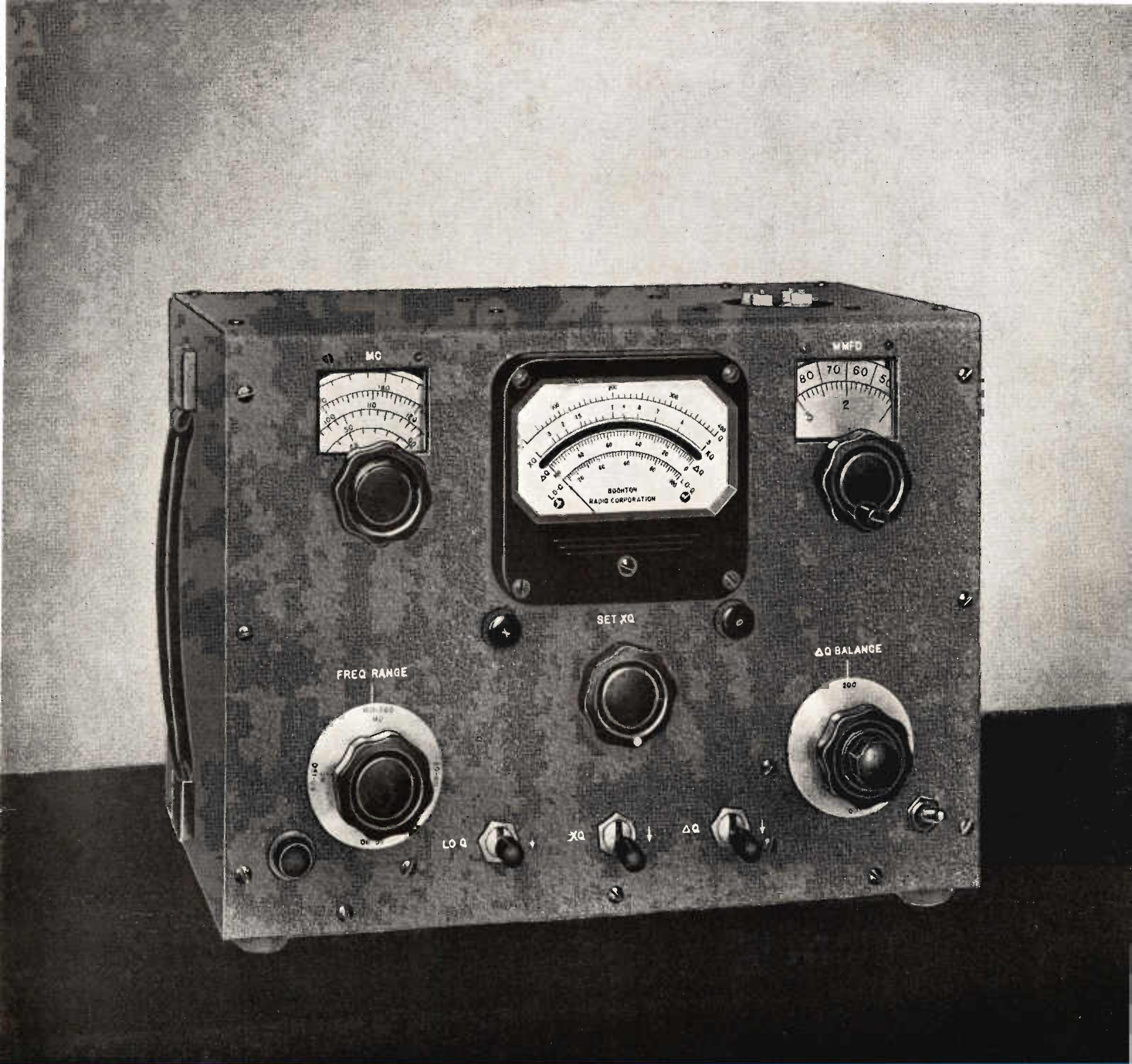
Electronic Engineering

JULY 1952

TWO SHILLINGS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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 : "Electronic Engineering," 28, Essex Street, Strand, London, W.C.2. 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 from Electrical Engineers for appointment in the Experimental officer class at a research establishment near Sevenoaks, Kent. (1) for maintenance of a wide variety of electronic instruments used by scientific staff. Experience with test and laboratory equipment including cathode ray oscillographic measuring equipment is desirable (Ref. D. 237/52A). (2) 3 posts Electrical and Electromechanical Engineers. To engineer experimental and prototype equipment for small scale production. A knowledge of the engineering of electronic equipment is desirable. (Ref. D. 238/52A). Candidates must have a minimum of Higher School Certificate with a science subject as principal subject but possession of a Degree, Higher National Certificate or equivalent qualification in Electrical Engineering may be an advantage. Salary will be assessed according to age, qualifications and experience within the inclusive ranges: Experimental Officer (minimum age 26) £597-£754. Assistant Experimental Officer £264 (at age 18) -£555. Rates for women somewhat lower. Posts are unestablished. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1., quoting Appropriate Ref. No. Closing date 11th July, 1952. W 2801

ASSISTANT (SCIENTIFIC) CLASS: The Civil Service Commissioners give notice that an Open Competition for pensionable appointment to the basic grade will be held during 1952. Interviews will be held throughout the year, but a closing date for the receipt of applications earlier than December, 1952, may eventually be announced either for the competition as a whole or in one or more subjects. Candidates must be at least 17½ and under 26 years of age on 1st January, 1952, with extension for regular service in H.M. Forces, but candidates over 26 with specialised experience may be admitted. All candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects: (i) Engineering and physical sciences. (ii) Chemistry, bio-chemistry and metallurgy. (iii) Biological Sciences. (iv) General (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing). Salary according to age up to 25: £236 at 18 to £363 (men) or £330 (women) at 25 to £500 (men) or £418 (women): somewhat less in the provinces. Opportunities for promotion. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1., quoting No. S 59/52. Completed application forms should be returned as soon as possible. W 2796

CROWN AGENTS FOR THE COLONIES. Assistant Engineer (Telecommunications) required for the London Office. Salary scale £575 × £25-£750 × £30-£900 a year. The £575 minimum is linked to entry at age 25 and is subject to increase at the rate of one increment for each year above that age up to, but not exceeding, age 34. Fully qualified officers of at least 27 years of age who have completed at least 2 years' satisfactory service are eligible, under certain conditions, for a special increase in salary of £75. Pay Addition to basic salary is payable at the rates of 10 per cent on first £500 and 5 per cent on next £500. Extra Duty allowance of 8 per cent on basic annual salary plus Pay Addition also payable at present. Engagement will be on unestablished terms, with a prospect, after satisfactory service, of appointment to the established and pensionable staff in due course, vacancies permitting. Candidates between 25 and 35 years of age should have passed the qualifying examination for Associate Membership of the Institution of Electrical Engineers, or equivalent examination. They should have served an apprenticeship or pupilage in Telecommunications engineering with a firm of repute and should have had practical experience of modern automatic exchange equipment. A knowledge of radio communications would be an advantage. Duties will entail the purchasing of all types of telephone, telegraph and radio apparatus involving the drawing up of specifications and adjudication on tenders. Previous contract experience is desirable. Apply at once by letter stating age, full names in block letters, and full particulars of qualifications and experience and mentioning this paper to the Crown Agents for the Colonies, 4 Millbank, London, S.W.1, quoting on letter M29255 B. The Crown Agents cannot undertake to acknowledge all applications and will communicate only with applicants selected for further consideration. W 2753

ELECTRONIC ENGINEERS required by Ministry of Supply in London. Qualifications : British, of British parentage; recognised engineering apprenticeship; corporate membership of one of the Institutions of Civil, Mechanical or Electrical Engineers or exempting qualification. Candidates should be familiar with large scale production in industry, and have good knowledge of radar principles and practices or lightweight and miniaturised electronic airborne equipment or modern ground radio-communications equipment. Practical experience of the types of equipment used by the R.A.F. an advantage. Duties: Planning production, progressing and assisting in clearing manufacturing and supply problems connected with a wide range of general radar equipment, or airborne radar equipment, or ground radio communications equipment. Liaison with industry, attendance at technical meetings and examination of expansion schemes. Salary: Two grades within the range £655 (at age 26)—£1,280 p.a. according to age, qualifications and experience. Opportunities occur periodically for established pensionable posts. Ref. No. D261/52A. Also Electronic Engineer Technical Grade I. Qualifications: Recognised engineering apprenticeship; knowledge of radio systems (including transmitters, receivers, arrays, etc.); experience in radio manufacture; capability to assess the potentialities of manufacturers' plant and to deal with production problems. Higher National Certificate or equivalent qualification desirable. Duties: Connected with production of radar and associated equipment, and co-ordination of industrial manufacture and Service requirements. Salary: within the range £733-£891 p.a. Opportunities for established pensionable posts may arise. Ref. No. D 262/52A. Application forms from Ministry of Labour and National Service, Technical & Scientific Register (K), Almack House, 26 King Street, London, S.W.1. Quoting appropriate Ref. No. W 2804.

UNIVERSITY OF BRISTOL. Applications are invited for two Lectureships (Grade II or III) in Electrical Engineering. Salary Scales £400 to £1,100, according to qualifications and experience, with F.S.S.U. benefits and family allowances. Candidates should have an Honours Degree and some relevant post-graduate experience. For one post, a power engineer with an interest in electrical measurements would be preferred : for the other, qualifications in high frequency radio are desired. Further details may be obtained on request, and applications should be sent within 3 weeks to The Registrar, The University, Bristol, 8. W 1501

UNIVERSITY OF EDINBURGH. Lectureship in the Department of Engineering. Applications are invited for the post of Lecturer in the Department of Engineering to commence duties on 1st October, 1952. The duties of the post include lecturing in the Post-Graduate Course in Electronics and Radio. The Salary Scale is £600 by £50 to £800 per annum though the commencing salary will depend on qualifications. Candidates should possess an Honours Degree in Electrical Engineering or Physics and should have had industrial or research experience. Applications containing the names of two referees and giving details of any published work, should be lodged, not later than 16th, July, 1952, with the undersigned, from whom further particulars may be obtained. Charles H. Stewart, Secretary to the University. W 2770

VACANCIES in Government Service. Skilled Craftsmen required for maintenance of Radio, Teleprinter and Electronic apparatus: also Assembler-Testers with experience of Telecommunications equipment by Government Establishments situated in (a) Middlesex and Kent. (b) Gloucestershire. Basic pay (a) £6 14s. 6d. (b) £6 12s. 0d. plus merit pay up to £2 10s. 0d. according to skill and experience. Paid annual and sick leave according to normal Civil Service Industrial Regulations. Opportunities of securing permanent and pensionable posts. Apply Box No. W 2811.

SITUATIONS VACANT

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

A WELL-KNOWN Midland Company requires an H.F. Heater Applications Engineer for test work on samples and the design of applicators. Men with metallurgical knowledge and at least H.N.C. should apply giving full details of qualifications and experience, quoting reference HFH to Box No. W 2748.

AN ENGINEER AND ASSISTANTS are required urgently by a large firm for work of national importance on the development of novel projects. Applicants should be thoroughly familiar with medium and high voltage grid controlled rectifiers and associated electronic equipment. Apply, giving full details of qualifications and experience and quoting reference IHG to Box W 2779.

APPLICATIONS are invited for the posts of Senior Designers and Senior Draughtsmen with a well-known West Country firm specialising in high class manufacture of scientific instruments. Experience is essential in one or two at least of the following fields: Development of electro-mechanical devices, servo-mechanisms, Electronic computing equipment. Applicants should be British by birth and at least 27 years of age. Write in the first instance with full details of past experience, whether married or single (assistance will be given in obtaining accommodation), full details of past career and qualifications. Interviews will then be arranged and expenses granted. Box No. W 2763.

APPLICATIONS are invited for the position of Electronic Engineer in the Aircraft Division of the English Electric Co. Ltd. at Warton. The successful applicant will be required to design and develop equipment for the measurement of physical variables encountered in the Wind Tunnel and Flight Test Departments. An Hons. Degree and a keen interest in this type of work is essential. Please write quoting ref. 985A to Central Personnel Services, English Electric Co. Ltd., 24/30 Gillingham Street, London S.W.1. W 2767

ARE YOU LOOKING FOR HARD WORK, interesting problems, and a reward proportional to effort? An engineering company on the outskirts of London engaged on an important guided weapon project requires several graduate Electronic and Mechanical Development Engineers and Technical Assistants for range work. Engineers should be British born between the ages of 25 and 30. Salaries range from £500 to £900 and depend on qualifications and experience. The project is new, and there are good prospects for promotion. Technical Assistants should have practical experience of

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conducting field trials of electronic and communications equipment. Experience of service radar and telecommunications equipment would be an advantage. Age range 25 to 30, salary range £500 to £700. Apply quoting ref. E.D. for Engineers and T.T. for Technical Assistants, to Box No. W 2771.

BELLING & LEE LTD., Cambridge Arterial Road, Enfield, Middlesex, require research assistants in connexion with work on electronic components, fuses, interference suppressors and television aerials. Applicants must be graduates of the I.E.E. or possess equivalent qualifications together with similar laboratory experience. Salary will be commensurate with previous experience: five day week, contributory pension scheme. Applications must be detailed and concise, and will be treated as confidential. W 138

CHARTERED PATENT AGENTS require University Graduate with Degree in Electrical Engineering and a sound theoretical knowledge of electronics. Knowledge of French an advantage, but not essential. No previous experience of patent work required. Applicant will be trained with a view to his becoming a Chartered Patent Agent. Commencing salary £450 to £500. Apply Mewburn Ellis & Co., 70/72, Chancery Lane, W.C.2. W 1514

DESIGN AND DEVELOPMENT ENGINEERS required for a newly formed laboratory in a large engineering company of national repute situated in the London area. Applicants should have a specialised knowledge of transformers, switches or variable condensers as applicable to the radio and television field. Good staff conditions operate and the post offers excellent prospects of advancement. Good salary to suitable applicants. Please write giving details of experience, quoting reference No. 1.68, to Box No. W 2787.

DESIGNER, with degree or H.N.C. and with experience in light mechanical engineering is required for work at Stanmore by the G.E.C. Research Laboratories, Wembley, Middx. This is a first class opening for an experienced engineer interested in working with experimental research and development teams. Apply to the Staff Manager (Ref. GBLC/S/177) stating age, qualifications and experience. W 2798

DEVELOPMENT ENGINEER required for design of High Frequency heating equipment. Minimum qualifications—Higher National Certificate in Electrical Engineering. Experience in H.F. Heating or Transmitter Development an advantage. Write in first instance stating age, experience and salary required to Philips Balham Works Ltd., 45 Nightingale Lane, Balham, S.W.12. W 2795

DEVELOPMENT ENGINEERS/PHYSICISTS. Senior positions with good prospects in connexion with the development of electronic computing and training equipment, including Flight Simulators. Experience in electronics essential. Good starting salaries, depending upon age, experience and qualifications. Location, near Waterloo station. Apply in writing to: Chief Engineer, Redifon Ltd., Broomhill Road, Wandsworth, S.W.18. W 2802

DRAUGHTSMEN senior and intermediate required in East London area by large company engaged in light electrical and mechanical engineering. It is essential that applicants should have experience of electronic components. Salaries will not be less than established rates and will be adjusted according to ability and experience. Interesting class of work and excellent working conditions. Pension Scheme in operation. Please write giving details of experience, quoting reference I.97, to Box No. W 2815.

DRAUGHTSMEN, Senior and Junior required. Experience in Electronics and Light Electrical Engineering an advantage. Apply by letter, stating age, nationality and experience to E.M.I. Engineering Development Ltd., Penleigh Works, Wells, Somerset. W 1414

DRAUGHTSMEN AND DRAUGHTSWOMEN. A few interesting vacancies exist in the Plessey Company Ltd., Vicarage Lane, Ilford, for experienced male or female drawing office staff in connexion with precision electrical and mechanical equipment. Salaries will be in accordance with age and experience. Apply, in writing, to the Personnel Manager, quoting reference C.W. W 2773

DRAUGHTSWOMEN. Owing to the shortage of well trained Draughtsmen a well-known firm of electrical and mechanical engineers in the greater London area is prepared to offer exceptional chances to Draughtswomen of proved ability either as full time or part time. They must be able to prepare complete layouts from engineers' sketches of either light precision mechanisms or alternatively electronic devices. Those having a bent for mechanical design must be used to specifying fits and tolerances appropriate to precision apparatus. Salaries will be on a generous scale according to age and experience. Apply quoting ref. E.M. to Box No. W 2772.

E. K. COLE LTD. (Malmesbury Division) invite applications from Electronic Engineers for permanent posts in Development Laboratories engaged on long-term projects involving the following techniques: 1. Pulse Generation and Transmission. 2. Servo Mechanism. 3. Centimetric and V.H.F. Systems. 4. Video and Feedback Amplifiers. 5. V.H.F. Transmission and Reception. 6. Electronics as applied to Atomic Physics. There are vacancies in the Senior Engineer, Engineers and Junior Grades. Candidates should have at least 3 years' industrial experience in the above types of work, together with educational qualifications equivalent to A.M.I.E.E. examination standard. Commencing salary and status will be commensurate with qualifications and experience. Excellent opportunities for advancement are offered with entry into a Pension Scheme after a period of service. Forms of application may be obtained from Personnel Manager, ECKO Works, Malmesbury, Wilts. W 2800

ELECTRO-MECHANICAL Engineers required with good academic qualifications, apprenticeship, theoretical background and knowledge of production methods for development work. Experience in electrical methods of computation, servo theory and instrument design desirable. Apply with full details of age, experience and salary required to the Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middlesex. W 2791

ELECTRONIC ENGINEER with good working knowledge of modern telephone practice and preferably sound recording, required for interesting new project with very big future. This is a top level job carrying a good salary and only engineers with the above qualifications and the ability to handle development and manufacturing problems need apply. Send copies of references, details of career and a recent photograph in the first instance to Box No. W 1482.

ELECTRONIC ENGINEER with Higher National Certificate and experience of circuit design required to work with Mathematicians (Honours Graduates) on a new electronic computing project. Outstanding opportunity, with good salary, for self-education. Apply, quoting reference S.P.I., to Employment Manager, Vickers-Armstrongs Limited (Aircraft Section), Weybridge, Surrey. Applications, with certain exceptions, are subject to the approval of the Ministry of Labour and National Service. W 2782

ELECTRONIC ENGINEERING COMPANY, Teddington area, requires electronic engineer with wide knowledge of industrial electronics, including pulse techniques, to take charge of development of new equipments. Well established company. Salary £1,250 plus. Good chance of becoming technical director, as present technical director will be going abroad to start foreign branch. Please state education and experience to Box No. W 1505.

ELECTRONIC ENGINEERS required for development work in the Gloucestershire area. Good academic qualifications and apprenticeship. Experience in one or more of the following desirable: Control systems, D.C. Amplifiers. Computing devices, Video Circuits, Microwave Techniques. Apply with full details of qualifications, age and salary required to Box AC72918, Samson Clarks, 57-61 Mortimer Street, London, W.1. W 2790

ELECTRONIC SERVICE ENGINEER, age about 25, H.N.C., required for maintenance and servicing of electronic equipment in large factory in the Watford area. Some development experience and ability is desirable. Salary £400/500 for good service engineer, or up to £600 for man with special qualifications. Please write stating age, qualifications and full details of experience to Employment Exchange, Water Lane, Watford. W 1498

ELECTRONIC TESTERS are required by the Nelson Research Laboratories, English Electric Co. Ltd., Stafford, in their expanding Electronics Laboratories. Applicants should have completed or be completing National Service and preference will be given to young men studying for higher qualifications. There are excellent opportunities for promotion to Laboratory work for the right type of man. Please write giving full details and quoting reference "English Electric 944" to Westminster Employment Exchange, Chadwick Street, London, S.W.1. W 2810

ELCONTROL LTD. (manufacturers of industrial electronic controls, have vacancies for the following, all of whom must have some experience of electronic manufacture and assembly: (a) Assistant to Chief Engineer to handle day-to-day problems. (b) Production charge hand. (c) Assembler used to prototypes, able to work from drawings. We are small but growing, and these are ground floor jobs for enthusiasts. Chief Engineer, Elcontrol Ltd., Wilbury Way, Hitchen, Herts. Phone: Hitchen 1598. W 2752

ENGINEERS for the maintenance of Digital Computers are required by the Computer Section of Ferranti Limited. Applications are invited from Engineers experienced in the servicing of large electronic equipments such as radar systems and predictors. Courses of instruction will be given to successful applicants, who will normally be based in Great Britain, although there will be opportunities for tours of duty abroad. Initial salary in accordance with experience and ability in the range £450-£700 per annum. The Company has a Staff Pension Scheme. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferrranti Limited, Hollinwood, Lancs. Please quote reference D.C. M.E. W 2814

EXPERIENCED COMPONENT ENGINEERS are urgently required by a large firm for work of national importance. Applicants selected will be required to build up a new section specialising in selection and design of electrical and mechanical components for electronic equipment, together with associated light and medium-heavy control gear, transformers and wiring. Applicants should have a full working knowledge of service specifications and type approval procedure, experience of component design and an understanding of ratings. Please write giving full details of experience and qualifications and quoting reference IHF to Box No. W 2780.

FERRANTI LIMITED, Edinburgh, require additional staff for their Engineering Division engaged on Electro/Mechanical instruments and radar equipment. Duties involve (a) the engineering and production design of new items to be put into production after the prototype has been evolved in the laboratories and (b) the clearing of technical snags during the various stages of production. Applicants should be fully qualified engineers and preferably have (a) Degree or Corporate Membership of one of the professional institutions (b) several years' experience in production design of instrument or radar equipment, and (c) knowledge of production methods. Opportunity for initiative; good prospects; staff pension scheme. Apply quoting reference "E.D." and give full details of training and experience in chronological order to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh. W 145

FERRANTI LIMITED, Manchester, have staff vacancies in connexion with long-term development work on an important radio tele-control project at their new laboratories at Wythenshawe, South Manchester. (I) Senior Engineers or Scientists to take charge of research and development sections. Qualifications include a good degree in Physics or Electrical Engineering and extensive past experience in charge of development work. Salary according to qualifications and experience in the range of £1,000-£1,600 per annum. Please quote reference WS. (II) Engineers and Scientists for research and development work in the following fields: Radar, radio and electronic circuits, micro waves, high power centimetric valves, vacuum and/or high voltage techniques, servo control and electro-mechanical devices. Qualifications include a good degree in Physics or Electrical Engineering or Mechanical Science, or equivalent qualifications. Previous experience is an advantage but is not essential. Salary according to qualifications and experience

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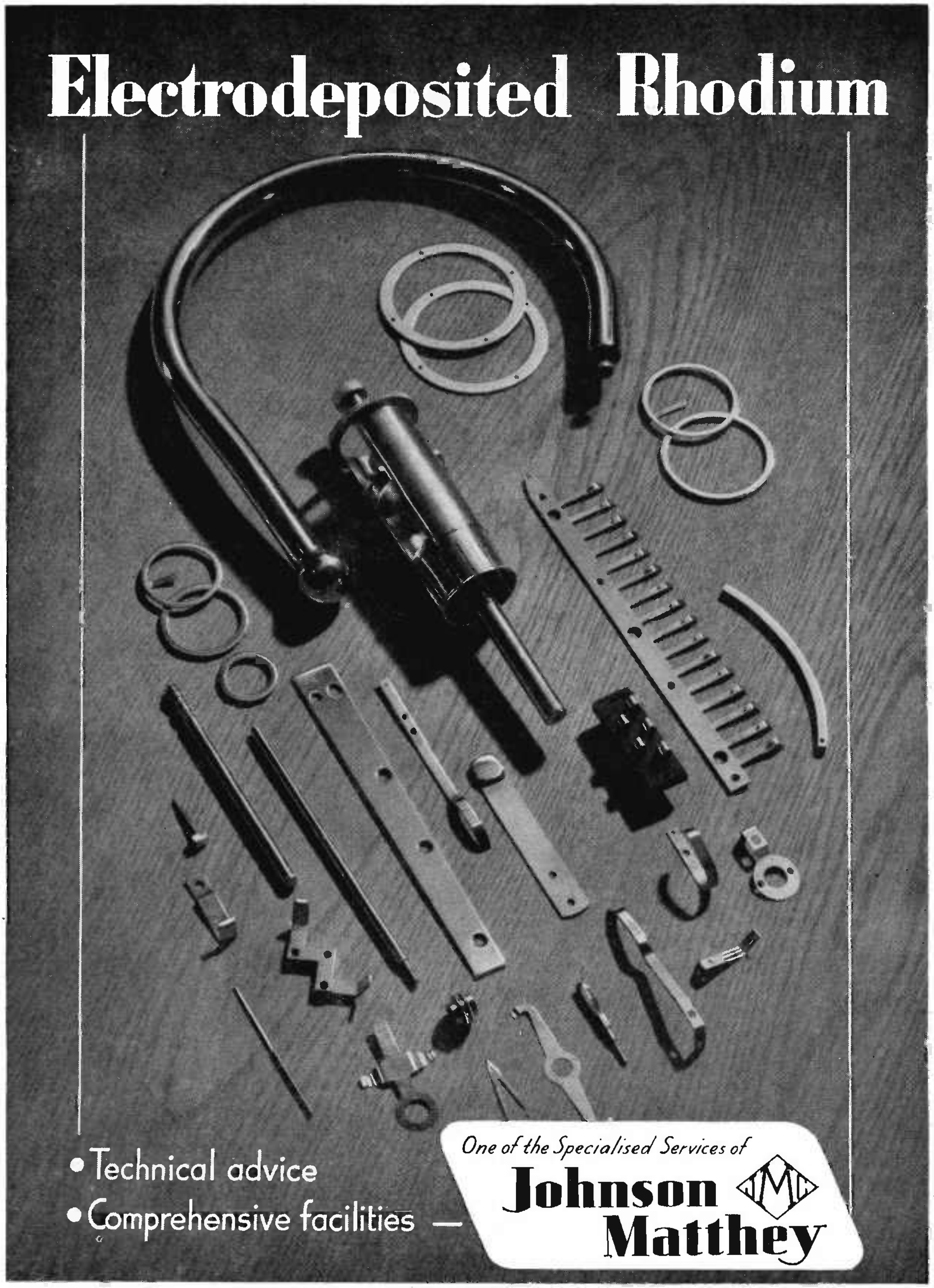
Electrodeposited Rhodium
• Technical advice
• Comprehensive facilities —
One of the Specialised Services of
Johnson Matthey
JMC

SITUATIONS VACANT (Cont'd.)

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in the range £500-£1,000 per annum. Please quote reference WE. (III) Technical Assistants for experimental work in the fields listed in (II) above. Qualifications required: a Degree or Higher National Certificate in Electrical or Mechanical Engineering or equivalent qualifications. Salary in the range of £400-£600, according to age and experience. Please quote reference WT. (IV) Designers and Draughtsmen. Section leaders, leading draughtsmen, draughtsmen and junior draughtsmen, preferably with experience in any of the fields mentioned above. Salaries based on A.E.S.D. rates: in the range £330-£850 per annum with good allowances for special qualifications and experience. Please quote reference WD. The Company has a Staff Pension Scheme. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti, Ltd., Hollinwood, Lancs. Please quote appropriate reference. W 2721

FIRST-CLASS Technical Representative required by leading manufacturers of High Frequency and allied equipment. Candidates should have sales ability with an electrical engineering background and preference will be given to those with successful sales record in this or allied equipment. Successful candidate will receive adequate technical training. The position offers good prospects and is pensionable. Write giving full details of education, training, experience, sales records and salary required—if possible sending photograph, which will be returned, to Box No. W 2792.

GENERAL ELECTRIC COMPANY have two vacancies for graduates for work at Stanmore. (A) An experienced man is required to take major responsibility for the design and operation of system test apparatus to be used in connexion with airborne radar equipment. (B) Physicist or engineer for work on electronic simulators. Apply in writing to the Staff Manager (Ref. GBLC/S/138) Research Laboratories of the General Electric Co. Ltd., Wembley, Middlesex, stating age, experience and qualifications. W 2786

GLASS BLOWER required by Ferranti Ltd. (Wythenshawe) for work on experimental microwave valves. Experience is required in normal laboratory glass-blowing and metal-to-glass sealing techniques. Salary according to age and experience in the range £500 to £800 per annum. Company has a Staff Pension Scheme. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference RQW. W 2762

GRADUATE in electrical engineering required for design development work in connexion with close-range gunnery. Experience with light current control circuits and/or servomechanisms an advantage. Applications giving details of age, qualifications, experience and salary required should be addressed to British Manufacture and Research Co., Ltd., Grantham, Lincs, quoting the reference AWK/MF/JH. W 1484

HIVAC LIMITED, the rapidly expanding Electronics Division of Automatic Telephone and Electric Co., Ltd., will shortly open new premises at Ruislip, Middlesex, with excellent modern facilities for the development and manufacture of miniature and sub-miniature valves, cold cathode tubes and other electronic devices. Applications are invited from Engineers, Physicists and Chemists with previous experience in the valve industry or in precision engineering for posts in the Development and Production Departments which occur as a result of this expansion. The appointments, a number of which will be for senior positions, will all be pensionable, offer splendid opportunities for advancement, and good salaries. Preference will be given to applicants with a University Degree in Physics, Engineering or Chemistry, or who are members of an appropriate professional body. Applications, stating age, full details of qualifications and experience, together with an indication of salary expected, should be addressed to The Managing Director, Hivac Limited, Greenhill Crescent, Harrow-on-the-Hill, Middx. W 2794

HONOURS GRADUATE in physics or engineering is required for work concerned with valve construction techniques. Previous experience in this field is desirable, but not essential. Apply in writing to the Staff Manager (Ref. GBLC/O/121) Research Laboratories of The General Electric Co. Ltd., Wembley, Middlesex, stating age, qualifications and experience. W 2778

IMPERIAL CHEMICAL INDUSTRIES LIMITED requires an Assistant Technical Officer (man or woman) to work on the applications of radio active and stable isotopes at their Fundamental Research Establishment at Welwyn. Applicants should have a knowledge of physics up to Degree Standard with some experience in electronics. Salary in accordance with age and experience. Replies to the Personnel Manager, Head Office and Regions Staff Department, Nobel House, 2 Buckingham Gate, S.W.1. W 2789

JUNIOR DEVELOPMENT ENGINEER required for high priority electronic and light mechanical work in equipment laboratory of Surbiton Surrey factory. Previous experience essential, and technical training to Higher National Certificate is desirable. Salary according to experience and qualifications. Five day week. Staff Pension Scheme and Bonus in operation. Write, giving full details to Box No. W 2783.

JUNIOR ELECTRONIC ENGINEERS and radio mechanics are required in expanding development department of well established electronic manufacturing company. Experience of industrial electronics and pulse techniques is an advantage. Please state experience and salary required to Technical Director, Winston Electronics Ltd., 1 Park Road, Hampton Hill, Middlesex. W 1507

LABORATORY TECHNICIAN Male (min. age 25 years) required for the Electron Microscopy Laboratory, Biophysics Department, National Institute for Medical Research, The Ridgeway, Mill Hill, N.W.7. Experience in electronics desirable. Salary according to age and experience. Permanent superannuated post after probationary period. 3-4 weeks holiday per year. Apply in writing to Administrative Officer at above address. W 2809

LABORATORY TECHNICIAN required for prototype construction of electronic and H.F. heating equipment. National Certificate standard. Write in confidence giving age, qualifications and details of experience to Personnel Manager, Standard Telephones & Cables Ltd., Warwick Road, Boreham Wood, Herts. Elstree 2401. W 2785

MULLARD LIMITED invite applications from Degree Engineers for a Technical Sales appointment in their Equipment Division based upon the Head Office in London. Applicants must have experience in the operational or systems-planning aspects of radio communication and/or broadcast transmitters and systems. The appointment is interesting and responsible, involving the technical and commercial handling and methodical organisation of a variety of products. Good prospects for advancement. Applications, which will be treated in confidence, should give full details of age, previous experience and salary required and should be addressed to the Personnel Officer, Mullard Limited, Century House, Shaftesbury Avenue, London, W.C.2. W 2756

MURPHY RADIO, LTD., have vacancies in an expanding programme covering the field of domestic equipment and many branches of Electronic development for Engineering and Physics, or similar qualifications. These posts are permanent and pensionable and offer good opportunities for advancement. Applications giving full details of qualifications and experience should be forwarded to the Personnel Manager, Murphy Radio, Ltd., Welwyn Garden City. W 2757

ONE SENIOR AND SEVERAL JUNIOR electronic engineers are urgently required by a large firm for work of national importance. Successful applicants will be required to take over experimental radar and other circuits, and to collaborate with experienced component and mechanical engineers in the development of soundly engineered equipment for quantity production. Applicants should have experience of layouts, allowance in circuit design for component tolerances, and an understanding of production methods. Please write, giving full details of qualifications and experience and quoting ref. IBA, to Box No. W 2781.

PHYSICIST or Applied Mathematician required by prominent engineering establishment in Northern Ireland to undertake original investigations in the field of guided weapons. Honours Degree essential, experience in one or more of the following desirable: (a) analysis of servo systems (b) aircraft stability (c) navigation (d) analogue computation or flight simulation. Good salary and prospects, assistance given with housing. Send full particulars of age, qualifications and experience to Box No. W 2784.

PHYSICISTS. Radio Engineers. Electronic Engineers. Positions for Senior and Junior Staff are available for Research and Development work on T.V., Electronics and Vacuum Physics. This Company is one of the Pioneers in the development of Television and is still in the forefront of Research and Development in this field. Our organisation is built up primarily to undertake Research and Development work, and we have a large Scientific and Technical staff engaged on an increasing Government and Commercial programme. Excellent opportunities exist for progressive work on new and interesting developments. Requirements for Senior Posts. A British University Degree, or its equivalent, in Physics, Electrical Engineering, or Communications Engineering. At least 5 years Post Graduate work on Research or Development. Successful applicants will be placed in charge of Research or Development projects being carried out by the Company. Requirements for certain Junior Posts. A British University Degree or its equivalent, in Physics, Electrical Engineering, or Communications Engineering. Practical experience not essential but an advantage. Requirements for other Junior Posts. Ordinary National Certificate or equivalent, in Physics, Electrical Engineering or Communications Engineering. 3 to 5 years experience on Research, Development or Design of Radio, Electronic or T.V. Equipment. Successful applicants for Junior posts will join groups working on Research or Development projects being carried out by the Company. Salary and facilities offered by the Company. Senior Engineers in range of £650-£1,000 p.a., Junior Engineers in range of £380-£650 p.a., depending on age, qualifications and experience. Pensions Scheme. 5-day week. Canteen facilities. Write, giving all particulars of experience, qualifications, age, etc., to Personnel Department, Cinema-Television Ltd., Worsley Bridge Road, Lower Sydenham, London, S.E.26. W 2806

QUALIFIED radio, radar, television and servo control engineers and optical system designers, as well as physicists interested in these subjects, wanted for important work of special interest. Posts permanent and progressive. Starting salaries from £450 to £1,000 per annum: a few more senior posts open. Apply, giving full details, to L. H. Bedford, Esq., Chief Engineer, English Electric Co., Ltd., Luton, Beds. W 2775

RADAR HANDBOOKS. Engineers required to prepare and edit technical reports and handbooks dealing with developments in radar and similar electronic equipment for a Company in the West London area. Applicants should have sound technical knowledge and be capable of clear expression with ability to find omissions and errors. The posts offer good salary and prospects for those who wish to combine their interest in electronics with writing. Please send full details to Box No. W 2776.

ROLLS-ROYCE LIMITED, Derby, have vacancies for Electronic Engineers experienced in maintenance and design of Electronic Equipment, to work upon the measurement of vibrations of Engines, etc. (Gas Turbine and Piston Types). Some mechanical knowledge, strength of materials, etc., an advantage. Higher School Certificate (or equivalent) or Higher National Certificate minimum requirement. Salary £400 to £650 p.a. (or higher for very well qualified men, according to experience). Apply to the Employment Manager. W 2766

SALES ENGINEER required by Company manufacturing light electrical equipment, Southern England, good general and technical education essential. Experience of manufacture of radio and other electronic equipment an advantage. Box No. W 1499.

SENIOR AND JUNIOR development engineers required for responsible work in radio and television development laboratories. Applicants for senior position should be able to undertake development work with minimum supervision. Excellent conditions and salary available for applicants who are accepted. Apply in first case to Chief Engineer, Radio Division, McMichael Radio, Ltd., Wexham Road, Slough, Bucks. W 2731

CLASSIFIED ANNOUNCEMENTS

continued on page 6

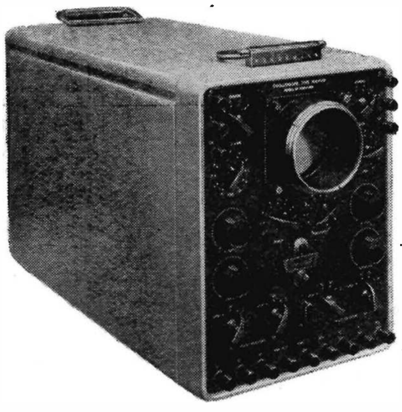
For Audio Frequency *work*

We have the tools

ELECTRONIC

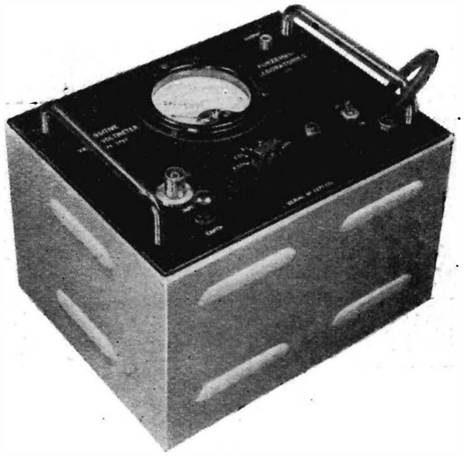
Furzehill LABORATORIES LTD

INSTRUMENTS

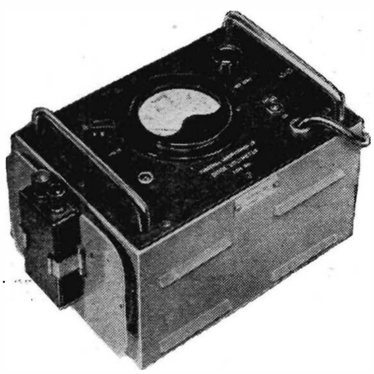


Cathode Ray Oscilloscope—1684D/2—a general purpose instrument—7mV/cm from d.c. to 1 Mc/s—servo audio, and T.V. work.

THE displayed instruments selected from the range of Furzehill equipment are of inestimable value to all engaged in Audio Frequency Engineering. Except for the B.F.O. the accuracy and ranges extend to the R.F. region.



Sensitive Valve Voltmeter—378B/2—1mV to 100V—10 c/s to 500 Kc/s—log voltage and linear dB scale.

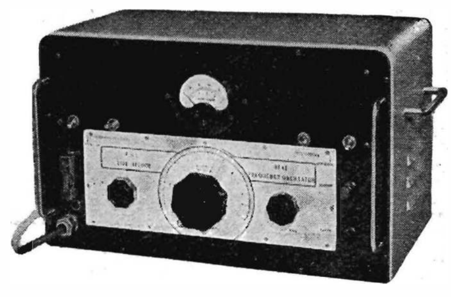


Diode Voltmeter—281C/2—50 c/s to 250 Mc/s, 0.1V to 150V a.c.—0.2 to 300V d.c.

THE following instruments are also available from current production—

- **Oscilloscope Camera**
- **A.F. Attenuator**
- **Resistance Box**
- **Stabilized Power Pack**

TECHNICAL specification price and delivery period for all instruments are available on request.



Beat Frequency Oscillator—AF200B—50 c/s to 20 kc/s—2 watts into 600 or 10 ohms—log scale to 1 kc/s.

Frequency Standard—1744—1 kc/s to 80 Mc/s—0.005% accuracy.

See also page 8

Furzehill **LABORATORIES LTD. · BOREHAM WOOD · HERTS** · ELSTREE 3940

SITUATIONS VACANT (Cont'd.)

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 inclusive or a woman aged 18-59 inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order, 1952.

SENIOR AND JUNIOR Electronic Development Engineers required. H.N.C. and Degree standard. Experience in U.H.F. and centimetric work an advantage. Apply by letter, stating experience, nationality and salary required, to E.M.I. Engineering Development Ltd., Penleigh Works, Wells, Somerset. W 1415

SENIOR APPOINTMENT — The Research Laboratories of the General Electric Co., Ltd., have a vacancy for a senior engineer or physicist at Stanmore (Middx) to direct a small research team working in radio-communications and radar problems. He must be interested in the fundamental aspects of such work and be familiar with centimetric measuring techniques, circuitry, aerials and propagation. He will also be called upon to advise project groups working in these fields. Attractive salary commensurate with experience and qualifications. Apply to the Staff Manager (Ref. GBLC/S/176) Research Laboratories of the General Electric Co., Ltd., Wembley, Middx. W 2797

SENIOR DRAUGHTSMEN required for work on light current electrical and electronic equipment. Must be familiar with R.C.S. 1,000 specifications and production requirements. Technical standard to at least O.N.C. or equivalent. Write quoting Ref. ADD to Box No. W 2602.

SENIOR ELECTRONIC ENGINEERS required for interesting development work. Applicants should have a sound theoretical knowledge with a Degree or equivalent in physics or engineering and previous experience of the design of prototype electronic equipment. A special knowledge of microwave techniques would be desirable. Applicants should write, giving full details to: Personnel Department, (ED/75), E.M.I. Engineering Development Limited, Hayes, Middlesex. W 2758

T.C.C. invite applications for positions as follows: (1) Technical Sales Representatives for radio and electrical industries, in Southern (London) and Northern areas. (2) Sales Office supervisors and assistants with knowledge of industry and ability to handle semi-technical correspondence. Write (in confidence) stating age, experience, salary required and which position applied for, to Sales Director, Telegraph Condenser Co., Ltd., North Acton, W.3. W 2713

TECHNICAL ASSISTANTS are required by the Research Laboratories of the General Electric Co. Ltd., Stanmore Common, Stanmore, Middx., for interesting research and development work in connexion with guided missiles. Applicants should have previous experience in electronics and should have received a technical education up to about National Certificate standard although possession of this qualification is not essential. Apply in writing to the Staff Manager (Ref. GBLC/KJS/944) giving full details of age, education and experience. W 2807

TECHNICAL SALES ENGINEER with several years experience and a knowledge of Electronic Test Equipment is required for a vacancy which has been created by company expansion. This is a permanent and progressive position with a company now in its 25th year. Reply in confidence with full particulars to Sales Manager, Furzehill Laboratories Ltd., Boreham Wood. W 2812

TECHNICIAN required to take charge of Vacuum Physics Dept. University Degree not necessary but previous experience in development and production of photo-electric cells and other electronic devices essential. Salary according to experience and ability. Write to Cinema-Television Ltd., Rotunda Building, Crystal Palace, S.E.19. W 2764

THE GENERAL ELECTRIC CO., LTD., Browns Lane, Coventry, have vacancies for Development Engineers, Senior Development Engineers, Mechanical and Electronic, for their Development Laboratories on work of National Importance. Fields include Microwave and Pulse Applications. Salary range £400-£1,250 per annum. Vacancies also exist for Specialist Engineers in component design, valve applications, electro-mechanical devices and small mechanisms. The Company's Laboratories provide excellent working conditions with Social and Welfare facilities. Superannuation Scheme. Assistance with housing in special cases. Apply by letter stating age and experience to The Personnel Manager (Ref. CHC). W 2717

THE PLESSEY COMPANY LIMITED, Vicarage Lane, Ilford, have an immediate vacancy for a Graduate Engineer between the ages of 25 and 35 with an interest in light electro-mechanical devices and another for an electronic circuit designer. Applicants must be British born, and should preferably have had some experience in design work in these fields. The posts are progressive and pensionable, and are in a newly formed division of the company. Salaries will be in accordance with age, and experience. Application should be made, in writing, to the Personnel Manager, quoting reference G.C. W 2774

THE GENERAL ELECTRIC CO., LTD., Research Laboratories, Wembley, Middx., have vacancies for engineers and physicists for electronic research and development work in the microwave field. Applications will be considered from graduates and also from men with rather lower qualifications. Write to the Staff Manager (Ref. GBLC/S/178) stating age, qualifications and experience. W 2799

TRANSFORMER ENGINEERS required by large company situated in the London area. Applicants must be fully conversant with the design of all types of transformers (1,000 VA rating), associated with radio, electronic and telecommunication equipment. Progressive and permanent appointment. Please write in confidence giving details of experience, quoting reference No. I.61, to Box No. W 2788.

T/V JUNIOR ENGINEERS required for the testing of Cameras and Associated Equipment. State details of television experience and education, Degree standard not necessary. This work offers good training and prospects in this field. Minimum starting salary £425 p.a. Apply to Box No. W 2750.

Further " Situations Vacant " advertisements appear on page 50 in displayed style.

SITUATIONS WANTED

ADVERTISER, with a good knowledge of Flexible Wave-guide theory, practice and manufacture, wishes to contact a Manufacturer considering an extension in his activities to include this new line. This is a sound offer from a qualified man with excellent experience in this specialised field, useful industrial and Government Department contracts, and up-to-date information on Services requirements. The advertiser can also advise on the commercial and export possibilities. All replies will be treated confidentially and should be addressed to Box No. W 1508.

CANADA. Advertiser bi-lingual English, French, some Spanish, widest experience design and manufacture complicated electronic and optical instruments, well travelled and well read. Technically ruthless, familiar present boundaries of most pure and applied science ponders possibility starting some unit, Montreal area preferred. Suggestions welcomed. Strict confidence. Box No. W 1510.

ELECTRONIC ENGINEERS (Aged 21-23) having just completed 5 year apprenticeship, with H.N.C. in electronics, require suitable posts. Home or Abroad. Box No. W 1511.

ELECTRONIC ENGINEER, age 27, Graduate of a famous Scottish Engineering College, Graduate I.E.E., experience in charge of small laboratory, requires progressive post which gives scope for ability and initiative. Small firm preferred, anywhere in British Isles. Box No. W 1513.

HIGHLY QUALIFIED Electrical Engineer, skilled, lucid and expert Technical Writer, offers held in drafting or revising MSS, Reports, Theses, etc. Box No. W 1504.

LAB. MECHANIC (28). Experienced in fitting, machining, sheet metal work, welding, etc., for electronic equipment and electro-mechanisms. London area. Box No. W 1515.

T.W.I. TRAINER (30). 8 years Naval Education Officer (Radio, Radar, General). Qualified Teacher seeks post in Industrial Education anywhere. Box No. W 1512.

FOR SALE

AMERICA'S famous magazine Audio Engineering, 1 year subscription 28s. 6d.; specimen copies 3s. each. Send for our free booklet quoting all others; Radio Electronics, Radio and Tele. News, etc. Willen Limited (Dept. 9), 101 Fleet Street, London, E.C.4. W 108

CONSTANT VOLTAGE TRANSFORMER. Oil immersed. Output to 1 per cent. Tapped 200/250 volts. 750 watts. Sine wave output. £25. Telephone Frobisher 3479. Box No. W 1502.

COSSOR D/B scope mod. 339 excellent condition. £36. 10s. Mullard audio BFO mod. E810, as new, £47. 10s. W. Radwan-Kuzelewski, 129 Portobello Road, W.11. Bay 8009. W 1506

ELECTRONIC ENGINEERING. June 1941 onwards, Wireless World January 1940 onwards, Proc. I.R.E. and Electronics January 1944 onwards, all copies in good condition. Offers to Box No. W 1503.

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

MINIATURE STEEL BALLS and Ball Bearings, Swiss and German Precision Work. Quick delivery. Distributors: Insley (London) Limited, 119 Oxford Street, London, W.1. Tel.: Gerrard 8104 and 2730. W 143

PANORAMIC Radio Adaptors. B.C.1031 for Receivers with I.F. 450/465c/s Max. sweep 100 + 100c/s 115/230 volts A.C. 50/70c/s. B.C. 1032 Navy Model Max. sweep 500 + 500c/s for Receivers with I.F. 5.5Mc/s. New condition, all with valves and Cathode Ray Tube. Send for special leaflet, " E.E." B.C.221 Frequency Meters 120kc/s to 20Mc/s Accuracy 0.005 per cent battery operated, supplied with all charts. Wavemeters R.C.A. T.E. 149 Accuracy 0.005 per cent 200kc/s to 30Mc/s. Relays. Magnetic Relays type 85, twin coil, large tungsten contacts 5 C/O 1 make and 1 break arranged in bakelite mounting with three fixed Resistors, new, 10s., post 1s. 6d. Send for latest list of Precision Instrument and Test Gear. Leslie Dixon and Co., 214 Queenstown Road, London, S.W.8. W 2793

POST OFFICE TYPE PANELS, chassis etc. Instrument cases and other sheet metal work to specification. Reasonable delivery. 19" × 10½" × ⅛" panel with chassis, brackets, instrument case rounded edges, chromium plated handles £3 19s. 0d. complete. Alexander Equipment Ltd. Childs Place, Earls Court, London. S.W.5. Frobisher 6762. W 1509

PURE BERYLLIUM FOIL, 0·005" thick and Beryllium Metal Discs for X-Ray Tube Windows: Elgar Trading Ltd., 240 High Street, London, N.W.10. W 141

TOROIDAL COILS wound, and latest potted inductors to close limits. Bel Sound Products Co., Marlborough Yard, Archway, N.19. W 139

WEBB'S 1948 Radio Map of the 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

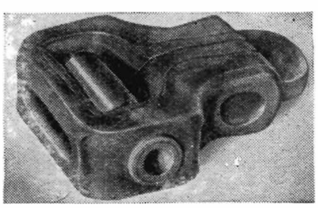
EDUCATIONAL

CITY & GUILDS (Electrical, etc.) on " No Pass—No Fee " terms. Over 95 per cent successes. For full details of modern courses in all branches of Electrical Technology send for our 144-page handbook—Free and post free. B.I.E.T. (Dept 337C), 17 Stratford Place, London, W.1. W 142

FREE. Brochure giving details of courses in Electrical Engineering and Electronics, covering A.M.Brit., I.R.E., City and Guilds, etc. Train with the Postal Training College operated by

CLASSIFIED ANNOUNCEMENTS
continued on page 8

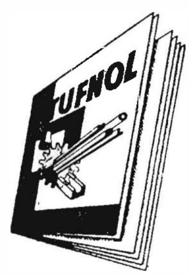
Though Tufnol is constantly seeking fresh worlds to conquer— these insulating collector bearing rings are not in fact a new use of this unique lightweight yet shock-proof material. As part of the apparatus in a steel works which swivels through 180° and charges the furnaces with steel ingots, they maintain 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.

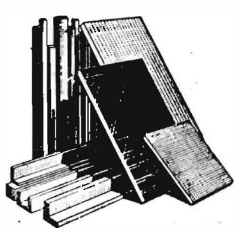


Tufnol bushes increase the life of pickers in textile looms and, furthermore, do not wear the spindles along which they are continually moving.

DOWN-TO-EARTH FACTS ABOUT TUFNOL . . .

are contained in literature 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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an Industrial Organisation. Moderate fees. E.M.I. Institutes, Postal Division, Dept. EE29, 43, Grove Park Road, London, W.4. (Associate of H.M.V.). W 2808

THE POLYTECHNIC, 309 Regent Street, W.1. Electrical Engineering Department. Head of Department: W. H. Date, B.Sc. (Eng.), M.I.E.E. Full-time day courses are provided in Electrical and Telecommunications Engineering. The courses, which extend over a period of three to four years, prepare for the Higher National Diploma and professional examinations and for the B.Sc.(Eng.) degree of the University of London. Session 1952-53 begins on September 16th, 1952. Evening Courses in the above subjects and also in Radio and Television Service Work commence on Monday, 22nd September. The courses prepare for the Ordinary and Higher National Certificates and for the City & Guilds of London Institute examinations. New students will be enrolled on 17th September, 5-8 p.m. Prospectuses may be obtained on application to the undersigned. J. C. Jones, Director of Education. W 2765

THE UNIVERSITY OF SOUTHAMPTON. Scholarship in Electronics. Applications are invited for a joint Post-graduate course in Electronics at the University of Southampton and at Vickers Armstrongs Ltd., Weybridge. The graduate selected will attend the Diploma course in Electronics at the University during the first year, and will spend the second year training in special projects in the Electronics Laboratory of the firm. The value of the scholarship will be that appertaining to the firm's graduate training scheme, approximately £400 per annum. Applications should be made to the Professor of Electronics, University of Southampton. W 2805

UNIVERSITY OF EDINBURGH. Principal: Sir Edward Appleton, G.B.E., K.C.B., D.Sc., F.R.S. Diploma in Electronics and Radio. The one year post-graduate diploma course in Electronics and Radio will commence on October 14th, 1952, and will provide specialised training for those wishing to proceed to research in this field, or to employment in industrial organisations. Applicants should hold an Honours Degree in electrical engineering, mathematics or physics. The main lecture courses are in network theory, principles of valve circuits, transmission and radiation theory, and particles in fields. Laboratory and field work will be arranged to support the lecture courses. A limited number of grants may be available for suitable candidates. Application forms, which should be completed and returned by July 16th, can be obtained from the Secretary to the University, The University, South Bridge, Edinburgh. W 2769

SERVICE

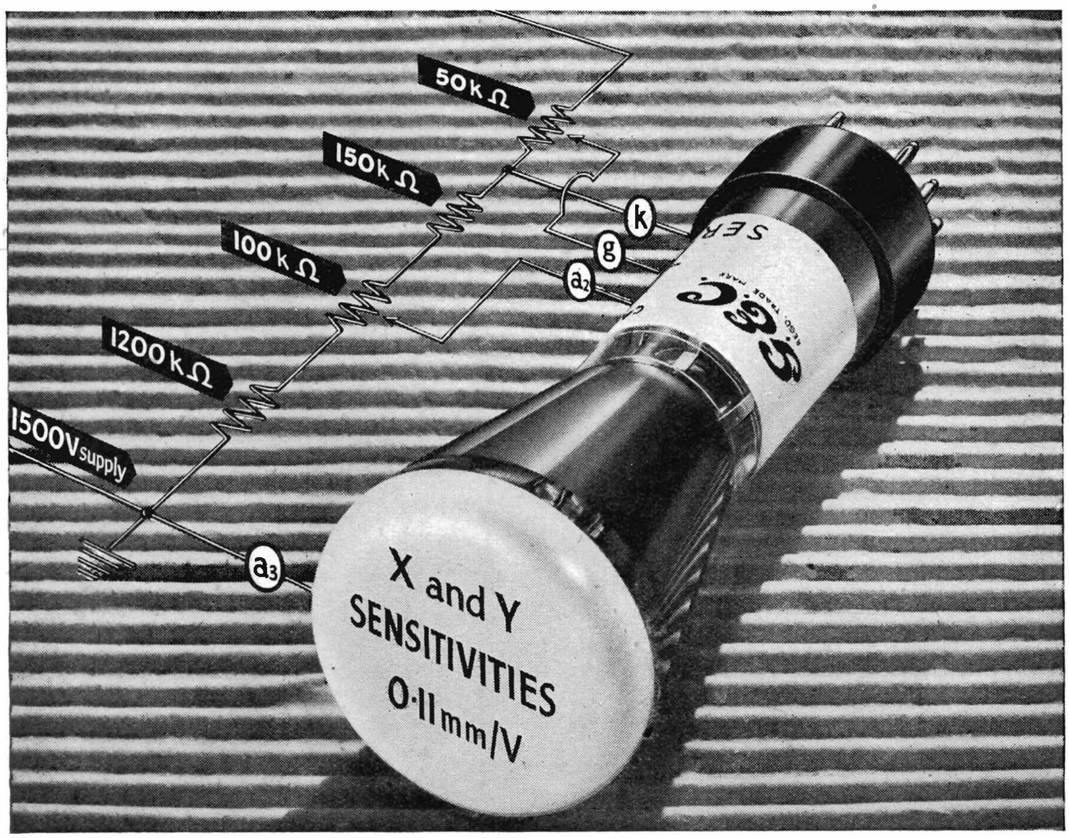
MACHINING: Capacity available for precision milling centre lathe turning and cutting of spur gears. Quantities 1-500. Also design of electromechanical mechanisms, drawing office facilities and special electronic equipment. Harvey Electronics Ltd., 273, Farnborough Road, Farnborough, Hants. Phone 1120. W 1500

MIDLAND concern manufacturing small precision parts for textile machinery can undertake additional work. Mixed labour force highly suitable for light assembly of small mechanisms. Box. No. W 2761.

TRANSFORMERS up to 20 K.V.A. chokes, solenoids and all types of associated equipment to specifications. Rewinds, repairs and overhauls. Good deliveries and quotations by return. Wilfio Products, 230/254, Brand Street, Glasgow, S.W.1. W 2777

PATENTS

IT IS DESIRED to secure the full commercial development in the United Kingdom of British Patent No. 623,181 which relates to Signal Reproducing Apparatus either by way of the grant of licences or otherwise on terms acceptable to the Patentee. Interested parties desiring copies of the patent specifications should apply to Stevens, Langner, Parry & Rollinson, 5 to 9, Quality Court, Chancery Lane, London, W.C.2. W 2768



G.E.C. instrument cathode ray tubes

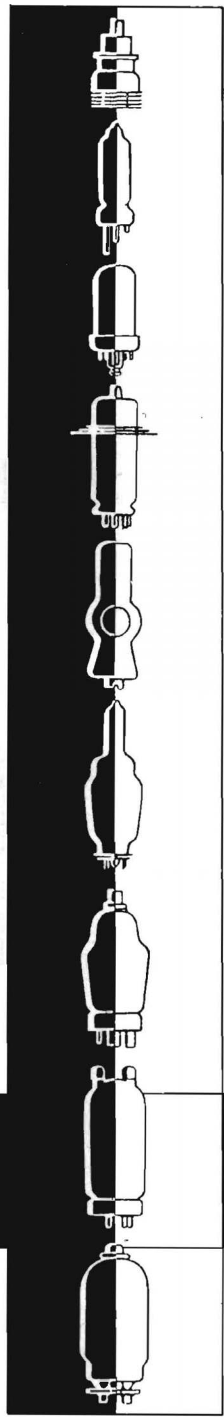
The above illustration shows a typical supply network suitable for the E4205·B·7; the deflection sensitivity increases as Va3 is reduced until it is 0.28 mm/V at the minimum of 600V. G.E.C. electrostatic instrument tubes are available in four standard sizes. All have 4V heaters and short-persistence green screens. Brief details are given in the table—for further information apply to the Osram Valve and Electronics Department.

Type No.	Bulb dia. (mm)	V_{a3}	Sensitivity (mm/V)		Base
			X	Y	
E4103·B·4	39	600-1000	$\frac{90}{V_{a3}}$	$\frac{100}{V_{a3}}$	B9
E4205·B·7	70	600-1500	$\frac{170}{V_{a3}}$	$\frac{170}{V_{a3}}$	B12B
E4412·B·9	90	600-4000	$\frac{350}{V_{a3}}$	$\frac{750}{V_{a3}}$	B12D
E4504·B·16	160	600-5000	$\frac{600}{V_{a3}}$	$\frac{1100}{V_{a3}}$	B12D

Special screens are available to order.

A range of specialised tubes is available for applications where normal types are unsuitable. Detailed information is available upon receipt of requirements.

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, LONDON, W.C.2



Communication and Industrial Valves

by *Standard*

The comprehensive range of high-quality valves manufactured by **Standard** includes types for almost every application, representative of which are:

Broadcast, Communication and Television transmission
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Microwave links
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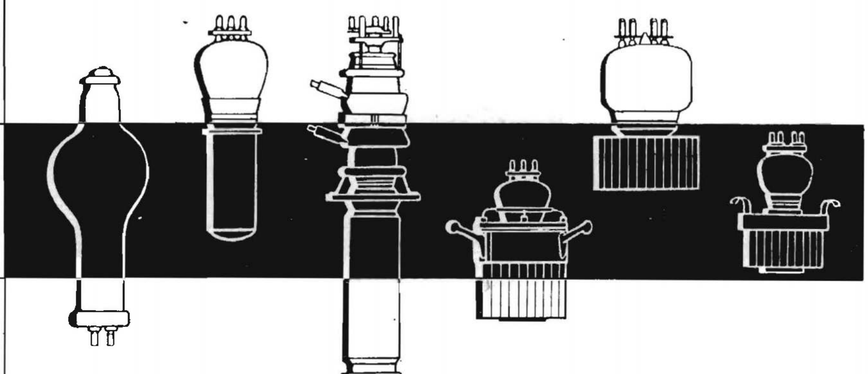
R.F. Heating
Counting and Computing
Motor Speed Control
Welding Control
Medical Diathermy
Voltage Stabilisation
X-Ray
Vacuum Measurement
Thermocouples



STANDARD engineers are available for consultation and their co-operation is assured to designers and technicians throughout industry wishing to take advantage of Standard's long experience in the field of valve engineering.

Please write to

Standard Telephones and Cables Limited

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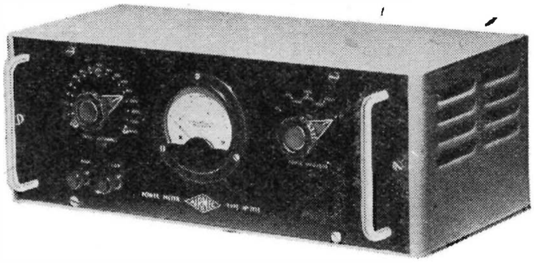
AIRMEC

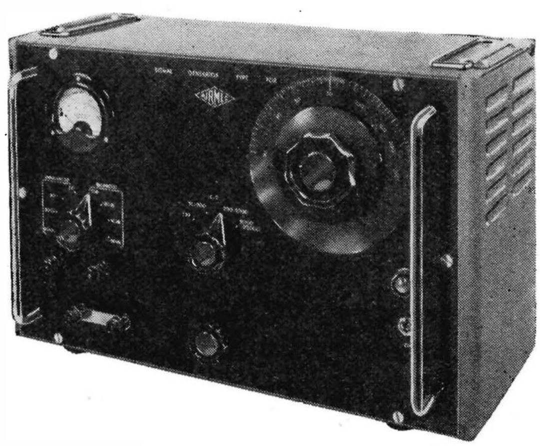
A. F. MEASURING EQUIPMENT



POWER OUPUT METER TYPE 708

- Frequency range of 30 c/s to 30 kc/s.
- Power range of 1 milliwatt to 20 watts.
- No tapped matching transformer employed.
- Input impedances purely resistive over complete frequency range.
- Seventeen input impedances from 2 to 5,000 ohms available by switching.
- Cannot contribute to the distortion when testing high-power amplifiers.

L. F. SIGNAL GENERATOR TYPE 702



- Frequency range 30 c/s to 30 kc/s.
- Frequency stability $\pm 0.05\%$ ± 0.5 c/s.
- A 600 ohm constant impedance attenuator provides steps of 20, 40, and 60 db of attenuation under all output conditions.
- A screened and balanced transformer enables balanced, unbalanced and fully floating ouputs to be obtained.

Full details of these or any other Airmec instruments will be forwarded gladly upon request.

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HIGH WYCOMBE · BUCKINGHAMSHIRE · ENGLAND

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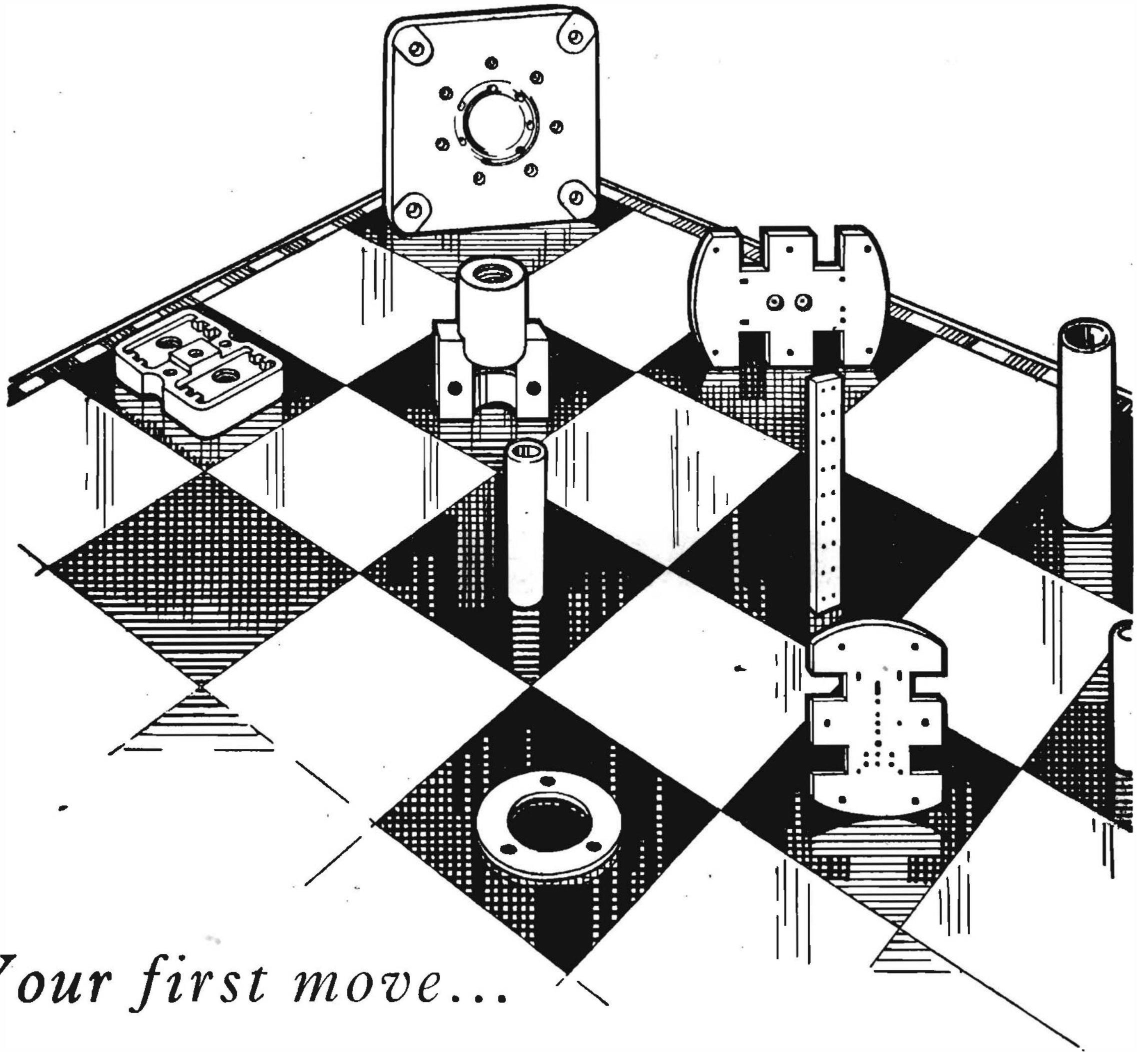
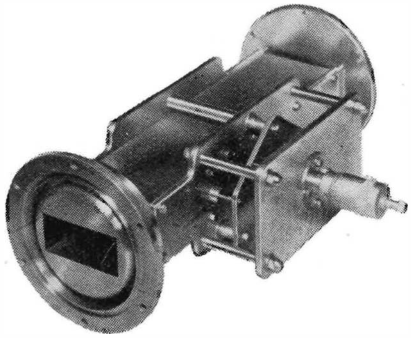


Microwave Test Gear

Metropolitan-Vickers Electrical Company announce a complete range of precision microwave test gear for use in 3 in. x 1½ in. waveguide over a band of wavelengths from 10 cm. to 11 cm.

1



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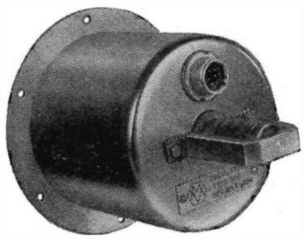

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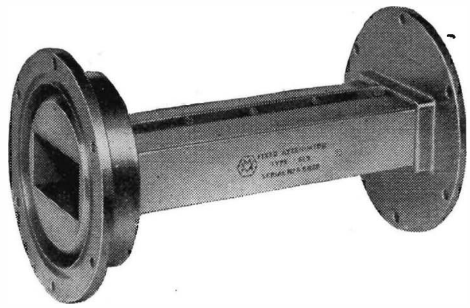

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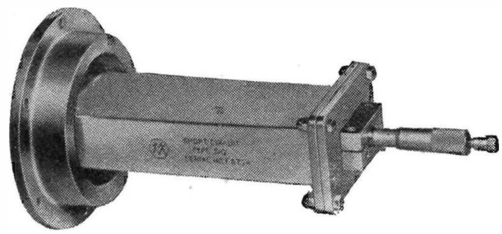

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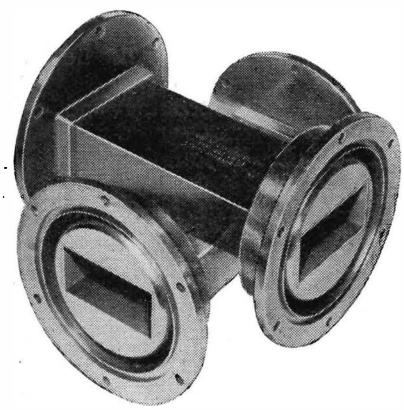


1 **PRECISION ATTENUATOR** Type 501

2 **MATCHED LOAD** Type 506

3 **OSCILLATOR** Type 508

4 **FIXED ATTENUATOR** Type 519

5 **SHORT CIRCUIT** Type 510

6 **DIRECTIONAL COUPLER** Type 504

Other Metrovick microwave equipment includes variable attenuator type 502, standing wave detector type 512, wave meter type 517, high power load type 515, S & X band spectrometer type 518.

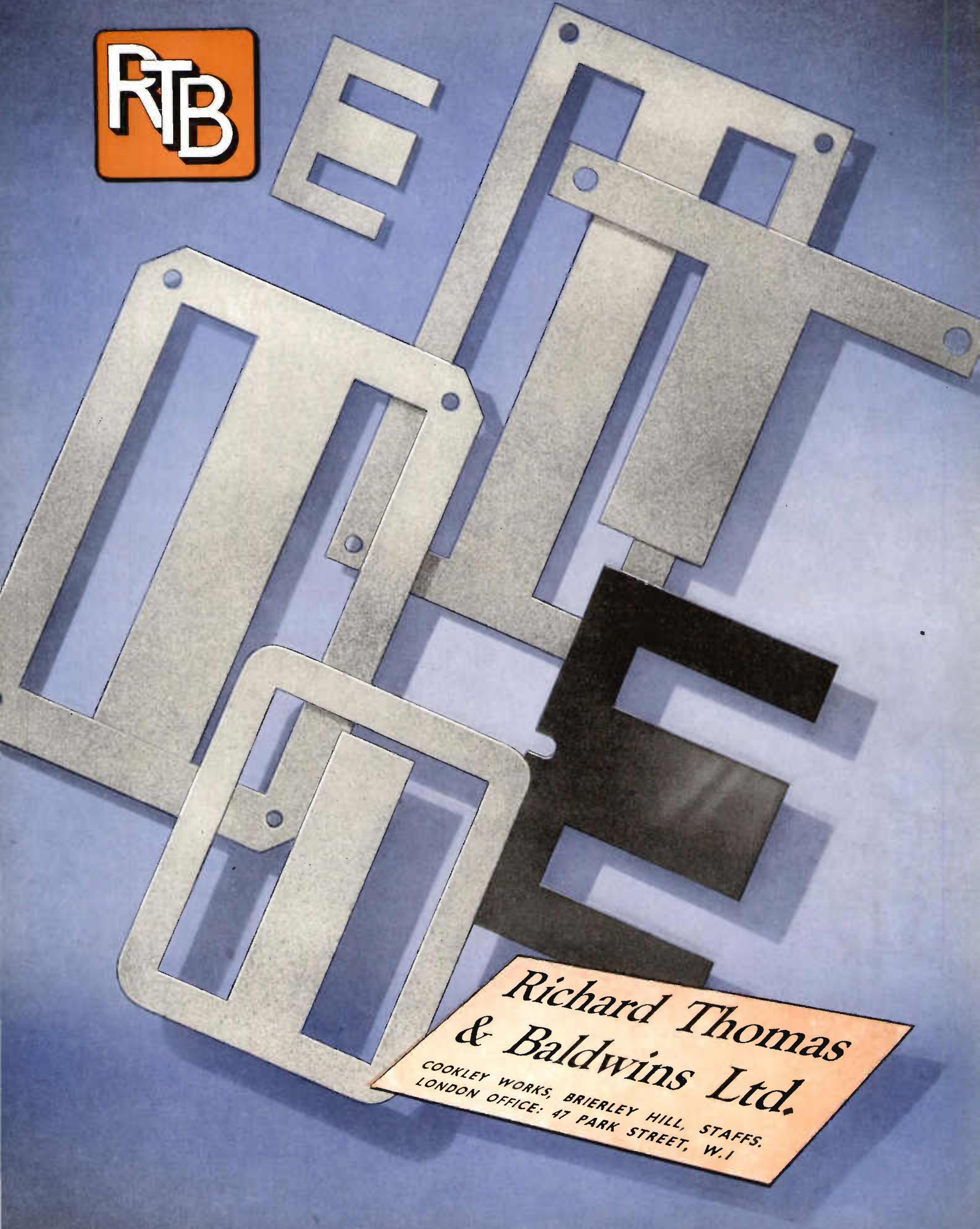
Full technical details will be sent on request.

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

Member of the A.E.I. group of companies

METROVICK Test gear for the microwave laboratory

R/E203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Manufactured to customers' specifications in gauges down to 50 s.w.g. and finer if required, "Cromaloy" V Resistance Wires are produced in long lengths to speed output by minimising time-wasting operational changes.
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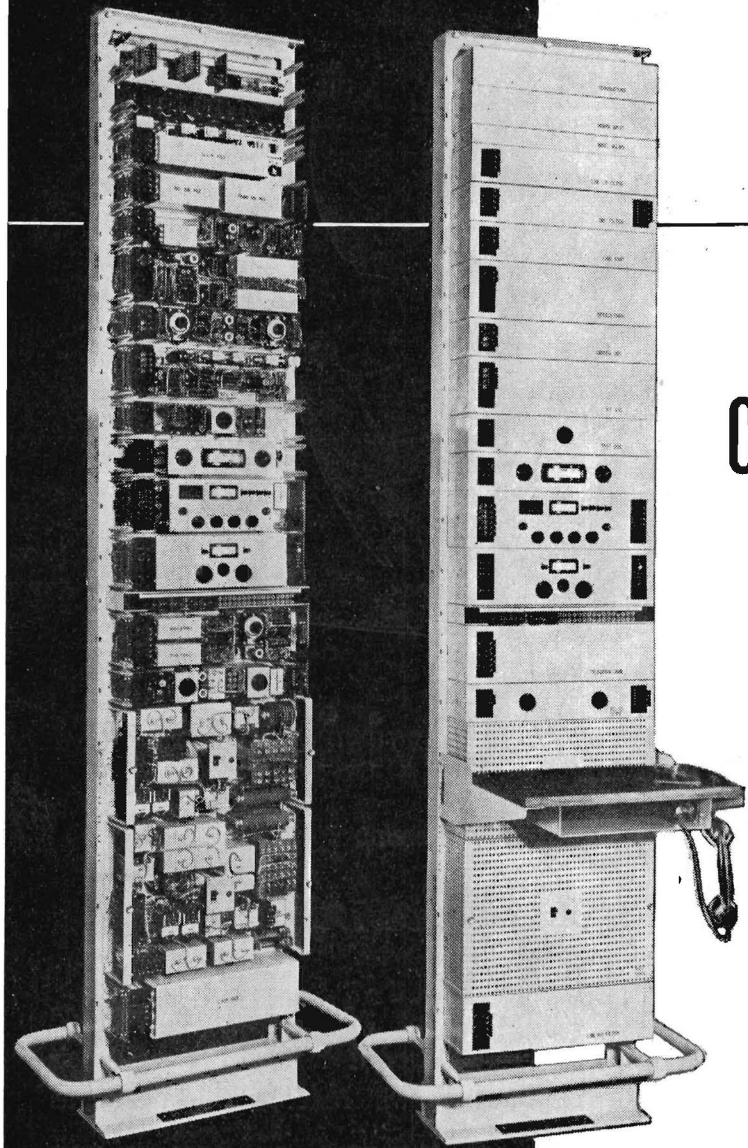

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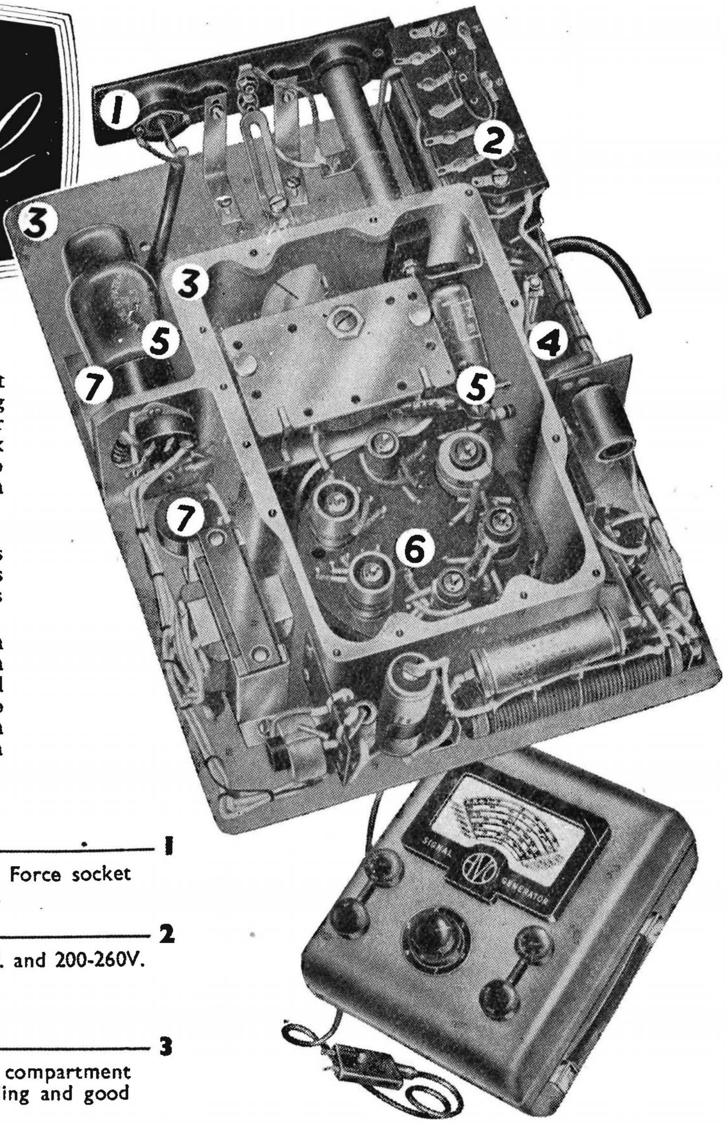

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150 Kc/s-500 Kc/s	5.5 Mc/s-20 Mc/s
500 Kc/s-1.5 Mc/s	20 Mc/s-80 Mc/s

Scale sub-divisions provide more than adequate discrimination for use in television circuits. Note the starred features below, which combine to maintain a minimum of less than 1μV. up to 20 Mc/s. and less than 3μV. between 20 Mc/s. and 80 Mc/s.

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Coaxial socket for attenuated output. Force socket located totally within H.F. compartment.

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Standard types run at a rating to ensure long life.

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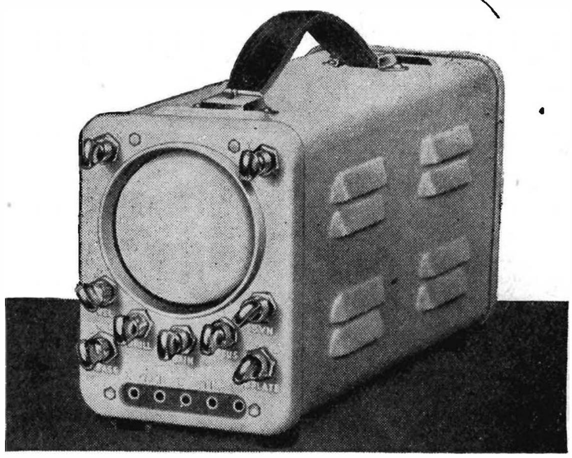

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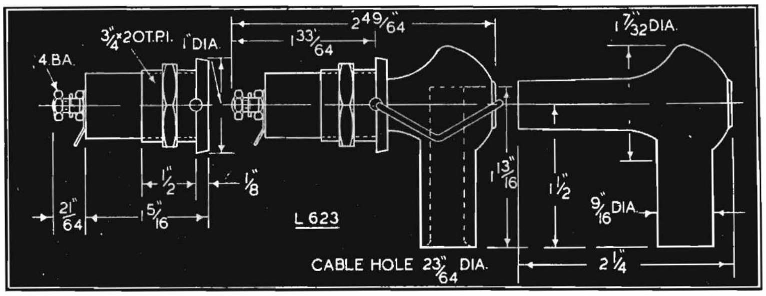

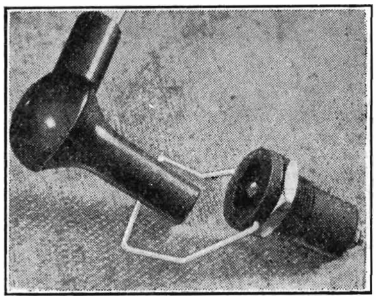

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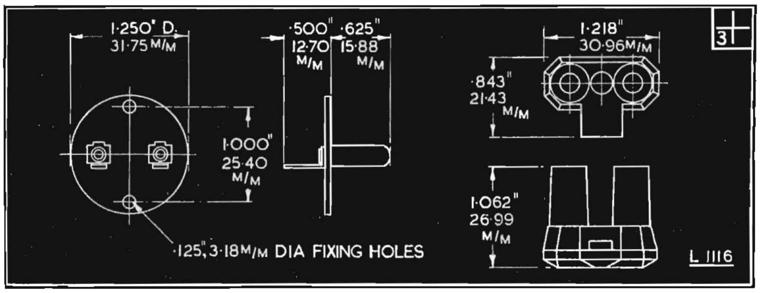

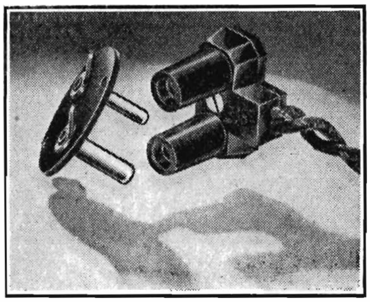

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L. 1116/S 2-POLE 5 AMP FLEX SOCKET

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Socket parts are shrouded for safe handling, and the turned brass inserts are resilient, ensuring positive contact. Efficient cord grip with side entry to discourage withdrawal by pulling cable. Grub screw loading; screw assembly.

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Electronic Engineering

Incorporating ELECTRONICS, TELEVISION and SHORT WAVE WORLD
Managing Editor, H. G. Foster, M.Sc., M.I.E.E.

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A Range of Thyratrons for Static and Mobile Applications

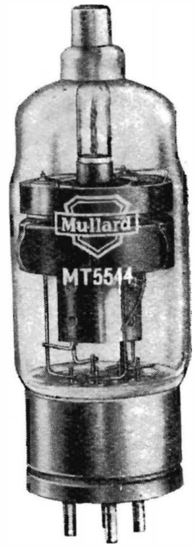
The Mullard range of thyratrons now includes types suitable for use in both static and mobile applications.

For static power and motor control applications a group of mercury-vapour valves is available, with anode current ratings ranging from 0.5 to 6.4 amperes.

For switching, servo mechanisms and motor control applications in aircraft, ships and mobile industrial equipments, there is a series of xenon-filled thyratrons available, with anode current ratings ranging from 0.1 to 6.4 amperes. On account of the small variations-with-temperatures of xenon, these tubes are specially suitable for use in equipments operating over a large ambient temperature range.

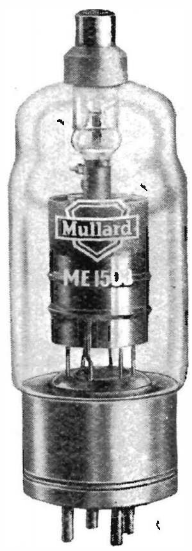
For special applications where extremely rapid rates of current rise are required, as, for example, in the modulation of radar transmitting systems, there is also a hydrogen-filled thyratron, the ME1503. This valve, characterised by its very low ionisation and de-ionisation time, is the first of a group of hydrogen thyratrons now being developed.

Brief technical details of the Mullard range of thyratrons are given below. More comprehensive information will be gladly supplied on request.



TYPE	DESCRIPTION	BASE	V_a (pk) max. (KV)	PIV max. (KV)	i_a (pk) max. (A)	I_a (av) max. (A)
MERCURY-VAPOUR						
MT17	Triode	4-pin UX	2.5	5.0	2.0	0.5
MT57	Triode	4-pin UX	1.0	1.0	15	2.5
MT105	Tetrode	B4D	2.5	2.5	40	6.4
XENON-FILLED						
2D21	Tetrode	B7G	0.65	1.3	0.5	0.1
MT5544*	Triode	B4D	1.5	1.5	40	3.2
MT5545*	Triode	B4D	1.5	1.5	80	6.4
HYDROGEN-FILLED						
ME1503	Triode	B4D	8.0	8.0	60	0.015

** Supplies temporarily restricted to Government Contractors only.*



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Electronic Engineering

Vol. XXIV. **JULY 1952** No. 293.

Commentary

THE fifth annual Report of the Advisory Council on Scientific Policy leaves little doubt that the shortage of scientific manpower, particularly electrical, mechanical and chemical engineers, chemists and physicists, is still acute and is likely to remain so for some considerable time. If there is any consolation to be found, it is in the fact that the younger men and women who are contemplating a scientific career in these branches, can look forward to many years of useful employment and that the demand for adequately trained scientists and technologists is likely to increase.

The shortage of scientific manpower is largely a post-war development and a Committee on Scientific Manpower was set up in December 1950, under the chairmanship of Professor S. Zuckerman to "study the future needs of scientific and technological manpower for employment both at home and abroad." The present report which is based on their studies considers the problem under the headings: —

1. The supply of and demand for scientists during the current decade.
2. The steps to be taken to rectify any deficiencies in supply.
3. The quality of our scientific manpower.
4. The steps to be taken to improve the quality of our scientific manpower.

In dealing with the present supply and demand, the Committee emphasizes the wide difference that exists between the state of affairs in this country and in the United States. Allowing for the difference in the available manpower of the two countries, it appears that America is turning out, and therefore presumably employing, nearly three times the number of scientists that this country is producing, and plans are already being made to still further increase her training facilities. In actual numbers during the year 1949-50 the total of American University degrees awarded in science and technology was about 110000, whereas here the number of University degrees as well as Higher National Certificates and Diplomas was only 14000.

This is a most disturbing situation which the Committee recognizes, and it is not easy to see how this gloomy state of affairs can be remedied. If we are to maintain our position in the world of trade and to improve our standard of living then there must be, as has so often been stated, a considerable increase in the efficiency of our production. There are several remedies which could be applied immediately and which would go some way to solving our present difficulties. for example an improvement in the present day indsutrial relationships and a lessening of world tension, and we think that still greater use could be made of the techniques which have been already made available. Essentially, however, the solution can only be obtained by a greater supply of scientific manpower for industry.

There will always be some demand for unskilled labour and not all manufacturing and construction methods lend themselves to extensive mass production techniques, but it is obvious that the craftsman of the bygone years must be replaced by the technologist in large sections of industry.

This implies a new generation of adequately trained scientists and technologists who, in the words of the Report, are "able to apply the latest results of scientific research to practical problems of production." The numbers coming forward will, however, not be high for we are a rapidly ageing population—in 1911 the proportion of the population 65 years and over, that is the section who are normally retired, was 53 per 1000, which figure rose to 105 in 1947 and will, it is estimated, be 160 in 1977.

The problem therefore is a two-fold one of buildings and students. The Committee finds that while a few technical colleges could be geared up to increase their output of scientists without great difficulty, this will not be sufficient in itself and extensions to existing colleges and universities must be contemplated. No mention is made of the creation of new universities, but there is a hint that the foundation of a new technical college along the lines of the Massachusetts Institute of Technology has come to be accepted as an urgent necessity.

Extensions and new buildings by themselves are not the complete answer—they must be adequately equipped and, what is appearing more difficult, adequately staffed. For far too long teaching has been a depressed profession—underpaid and inadequately acknowledged, and we are now reaping the full reward for our neglect. It is not surprising therefore that the National Advisory Council on the Training and Supply of Teachers stated recently that the number of new recruits for the teaching of science and mathematics is only just sufficient to make good the ordinary wastage.

There may be economic difficulties in persuading larger numbers of the rising generation to stay at school until 17 or 18 years of age and then to proceed for further training, either full time or part time, with the co-operation of their employers. The present supply is by no means sufficient, for only 7 per cent of pupils remain at school after the age of 17, and only 3 per cent proceed to a university.

In contrast to the rather depressing reading which the Report makes, it is encouraging to learn that the quality of the present day scientist is beyond reproach.

Some New

Image Convertor Tubes

and Their Applications

By J. A. Jenkins,* M.A., A.Inst.P., and R. A. Chippendale,* B.Sc.

AN image convertor is an electron-optical device in which an optical image is converted into an electron beam. Normally, this beam impinges in turn on a fluorescent screen and a reproduction of the original image is obtained. Such an electron tube depends for its operation on photoelectric emission from a smooth surface, and on the property of electron-beams that they may be focused by electro-magnetic means in a fashion analogous to the formation of light images by optical lenses.

A simple diagrammatic representation of such a tube is shown in Fig. 1. The optical image is formed by lens L on photoelectric emission from a smooth surface, and on the highly evacuated glass bulb B. The photocathode emits electrons over its area in numbers proportional to the light distribution in the optical image. The electrons e are accelerated by the conductive cylindrical wall coating W whose potential is a few thousand volts, and are

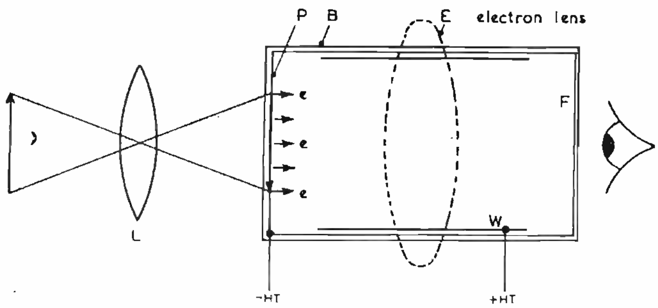


Fig. 1. Diagram illustrating the principle of the image convertor

simultaneously focused by the electron lens E on to the fluorescent screen F. On striking the phosphor, some of the electron energy is converted into light and an exact reproduction of the original optical image is obtained. The electron lens may be formed either by a suitably shaped electrostatic field, by a magnetic field, or by a combination of both.

Photocathodes

The photocathodes used in image convertors are "semi-transparent" and the electrons are emitted from the side opposite to the incident light. Two surfaces with widely differing spectral response curves are made by Mullards: the "A" surface of caesium-antimony and the "C" surface of caesium-oxygen-silver. The spectral response curves of these photosurfaces are compared in Fig. 2. It will be observed that the use of the "C" surface enables an image convertor to be used with radiation of wavelength longer than 6500A. The "A" surface is normally used for shorter wavelengths and its absolute sensitivity is many times the greater of the two. The caesium-antimony cathode is in fact the most sensitive photo-emissive surface known.

Viewing Screens

If a simple image convertor of the type shown in Fig. 1 is used with incident radiation in the visible region, two effects will combine to lower the efficiency of the device. Firstly, light from the object, passing through the photocathode, will illuminate the fluorescent screen and be visible through the phosphor, and secondly the fluorescing of the phosphor will illuminate the photocathode giving rise to a regenerative effect. The magnitude of these effects depends

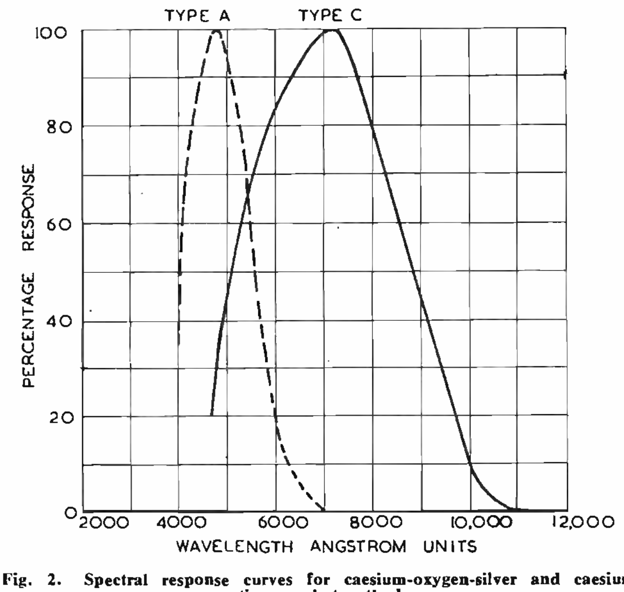


Fig. 2. Spectral response curves for caesium-oxygen-silver and caesium-antimony photocathodes

mainly on the distance between cathode and screen and on the brightness of the object under observation; but in general a lowering of contrast in the fluorescent image will result.

A solution to this problem is obtained by an "aluminium backing layer" on the phosphor[1]. A thin film of aluminium is tightly stretched across the back of the fluorescent screen and is opaque to light while at the same time allowing the passage of electrons accelerated by 6kV. The

*Mullard Ltd.

aluminium film also acts as a mirror, reflecting the light normally emitted from the back of the phosphor, so that it can make a useful contribution to the screen brightness. Further, the caesium vapour present in the tube during the formation of the photocathode is prevented from reacting with the phosphor and lowering its efficiency.

Willemite is the most commonly used phosphor, and its high efficiency and green fluorescence make it suitable for both visual observation at low light levels, and for photographic recording. The long decay time associated with this phosphor makes it unsuitable for some applications, and in these cases a blue zinc-sulphide treated with a "killer" to suppress afterglow is used. Zinc-sulphide is also used where the highest photographic recording speed is required. All the forementioned phosphors can be laid to form screens that will resolve 50 black and white lines per millimetre.

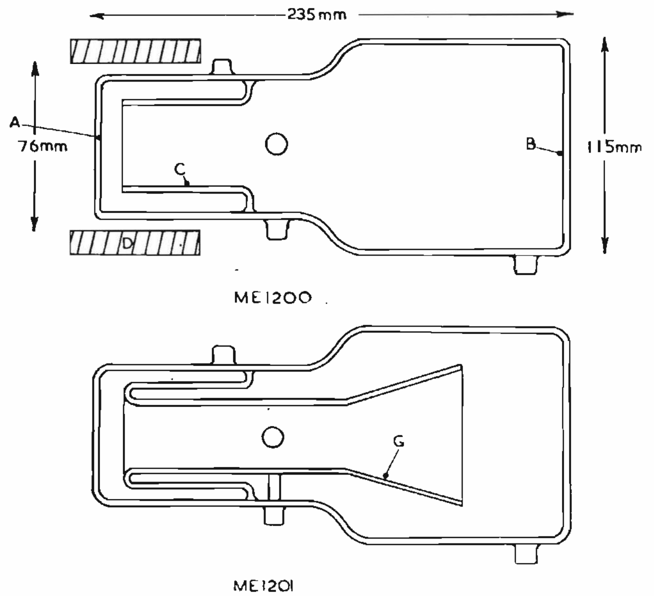
Some Infra-Red Image Convertors

It is clear that the production of a fluorescent image on the screen is dependent on the spectral response curve of the photocathode and on the nature of the light forming the optical image. Thus, if the photocathode is sensitive to radiation between 7,000 and 10,000A to which the human eye does not respond, a scene illuminated by such radiation can be made visible by means of the image convertor. This effect in the near infra-red region is obtained by the use of a caesium-oxygen-silver photocathode. Considerable effort went into the design and manufacture of infra-red viewing tubes during World War II and three main types were evolved to the Service requirements of America, Britain and Germany respectively. The tubes were the RCA 1P25, the E.M.I. CV144 and the A.E.G. image convertor [2,3,4,5,6]. They were designed with a specific application in view and have mostly proved to be of little value in some of the more recent techniques.

Dynamic Operation

In the case of the forementioned infra-red image convertors, the method of use can be regarded as "static operation," when the position of the electron beam is constant inside the tube and the flow of electrons to the screen is uninterrupted. The deflexion of the "electron-beam image" or its control by voltages applied to specially designed electrodes can be described as "dynamic operation," and it is only recently that such techniques have been successfully applied to new types of image-convertor designed with the problems of dynamic operation in view.

Fig. 3. Outline drawings of the ME1200 and ME1201



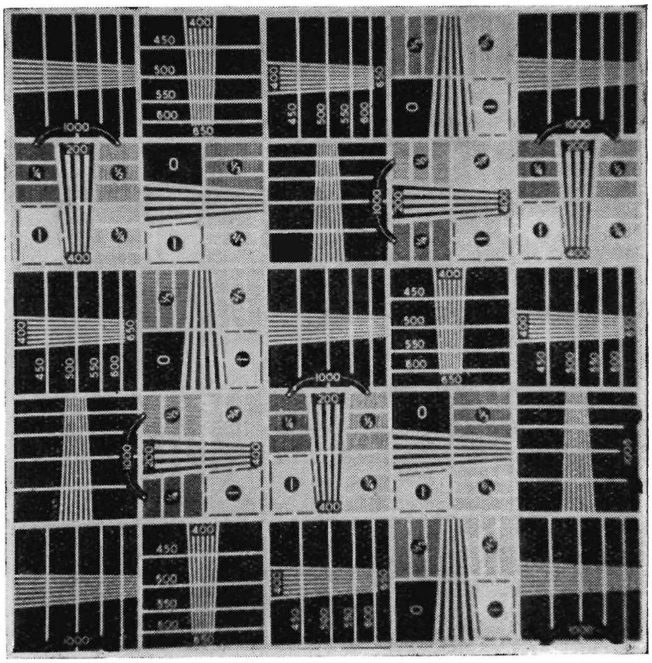


Fig. 4. Picture of a resolution chart recorded from the luminescent screen of an ME1200

Scanned Trace Photography with Very High Writing Speeds

Drum and mirror cameras are often used to study fast phenomena. Their writing speeds are limited by the ultimate strength and resistance to flexure of the moving parts, and speeds of one or two thousand metres per second can only be attained at considerable sacrifice in overall light-gathering power.

The Mullard ME1200 is a two electrode convertor which is suitable for scanning applications. Fig. 3 shows an outline of the tube. Photocathode A and aluminium-backed fluorescent screen B are on optically flat plates, and the internal wall and glass re-entrant C are coated with a layer of aluminium which can be connected externally to the fluorescent screen which normally operates at 6kV. Electromagnetic focusing is used and coil D enables a picture imaged on the photocathode to be focused on the screen with a linear magnification of up to four diameters. The focus coil is fed from a current stabilized pack as variations in magnetic field will defocus the picture. A resolution of 20 black and white lines per millimetre can be achieved on a picture filling the screen with a 1 per cent current stability in the focus coil. Fig. 4 is a photograph of a definition chart recorded from the fluorescent screen and shows the picture quality achieved under static conditions.

The tubes were first used by Dr. J. S. Courtney-Pratt[7,8], in an investigation of the growth of explosive reactions. Dr. Courtney-Pratt's method makes use of the features of an image convertor combined with a time-base deflexion system similar to any that could be used in a cathode-ray oscillograph. By avoiding the use of mechanically moving parts, the method is free from the inherent limitations of writing speed of all the earlier instruments. Vibration is eliminated, and this too, results in better definition and resolution. Wide aperture lenses can be used without difficulty, and the overall intensity compares favourably with that of the very best mechanical cameras.

Suppose the photosensitive surface of an image convertor tube is illuminated along a line AB as shown in the schematic diagram in Fig. 5. If the illumination is uniform, then with a standard tube a corresponding straight line of uniform intensity appears on the fluorescent screen. If a bright point image is caused to move along AB while a changing electric or magnetic field is applied across the tube, then the line traced on the fluorescent screen is diagonal. The inclination of this diagonal is a measure of the relative velocities of the image along AB and the rate of sweep of the time-base. Similarly, if the luminous image corresponding to any event is made to fall on AB while there is a changing deflecting field applied to the tube, a picture will appear on the fluorescent screen which is a function of the event and of the time-base sweep rate. This trace can be photographed with any ordinary stationary camera used with a time exposure equal to or greater than the duration of the event.

Fig. 6 shows the trace of detonating lead-azide as the luminous explosion front travels a distance of a few millimetres away from the point of initiation at a velocity of 2,000 metres/sec. The time-base writing speed in this instance was 24,000metres/sec.

The use of sweep speeds of greater than 10^5metres/second, together with a resolution of 20 lines per millimetre at the fluorescent screen, make it possible to resolve a time interval between two events of less than 10^{-9} second. Dr. Courtney-Pratt confirmed this experimentally

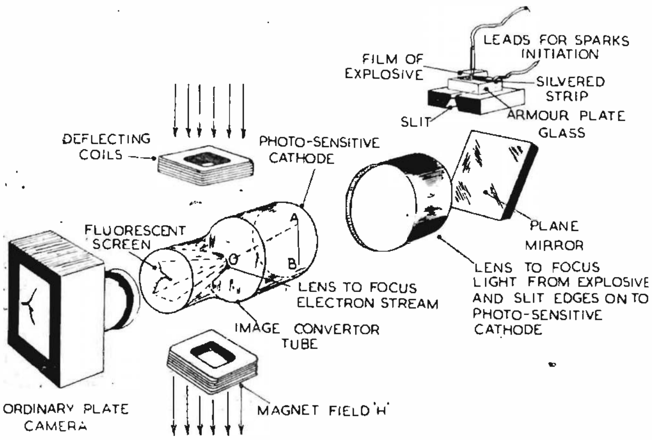


Fig. 5. Schematic diagram of the apparatus used to photograph the growth of explosive reactions

by using the method to measure directly the delay in arrival of a pulse of light that had travelled a path 2.6 metres longer than the direct path.

The ME1201

This tube has an internal grid electrode but is otherwise similar to the ME1200 (Fig. 3). The grid G is supported on a glass reentrant and is well insulated from both anode and cathode. With a potential of -60V on the grid and 6kV on the fluorescent screen, the normal electron stream from the cathode is suppressed, but a voltage of 2 to 3kV on the grid enables a good quality picture to be obtained on the screen. A picture can be obtained with grid voltages as low as 500V but with some distortion, and grid voltages of at least 2kV are used if high quality pictures are required.

The image convertor can be used as an optical shutter by the application of suitable voltages to the grid. The two-electrode ME1200 can also be used as a shutter by the pulsing of the full anode voltage across the tube, but where very high shutter speeds are required it is a considerable advantage to be able to control the picture by the application of lower grid voltages. When working as an

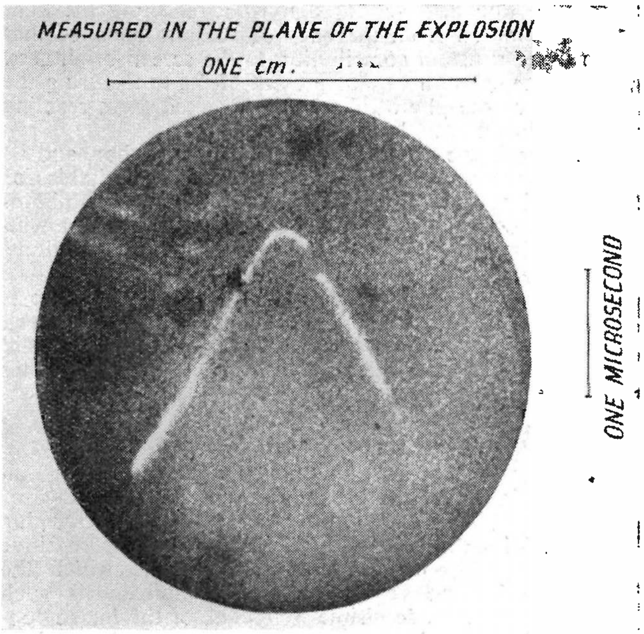


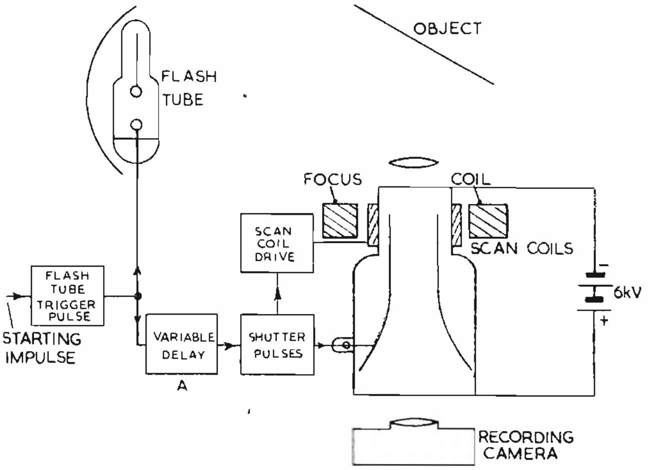
Fig. 6. Explosion trace for lead azide

optical shutter the image convertor is not limited in speed by the inertia of moving parts, as in the case of mechanical shutters. Its maximum speed and efficiency depend rather on the problems of the production of square voltage pulses for application to the control electrode. Fig. 7 shows a diagrammatic layout using the grid-controlled image convertor as a high-speed shutter. Scanning coils inside the focus coil enable drum camera type records to be made if required. For very short exposures of 10^{-6} seconds or less the opening of the shutter must be synchronized to the peak light output of the flash tube which is illuminating the object under observation. The flash tube normally used is the LSD.II, a high pressure, argon-filled tube of the Arditron type[9] which has a peak luminous intensity of 100×10^6 lumens.

A circuit for a high-speed camera which was developed by Dr. R. F. Saxe of A.R.E. for very high speed single shot photographic records is shown in Fig. 8 where the image convertor is shown diagrammatically. When the image tube is " shut," the tube voltages are:

$$V_c\ 3{\cdot}0\text{kV},\ V_g\ 2{\cdot}9\text{kV},\ V_a\ 6\text{kV}.$$

Fig. 7. The grid-controlled image convertor set up as a high-speed camera



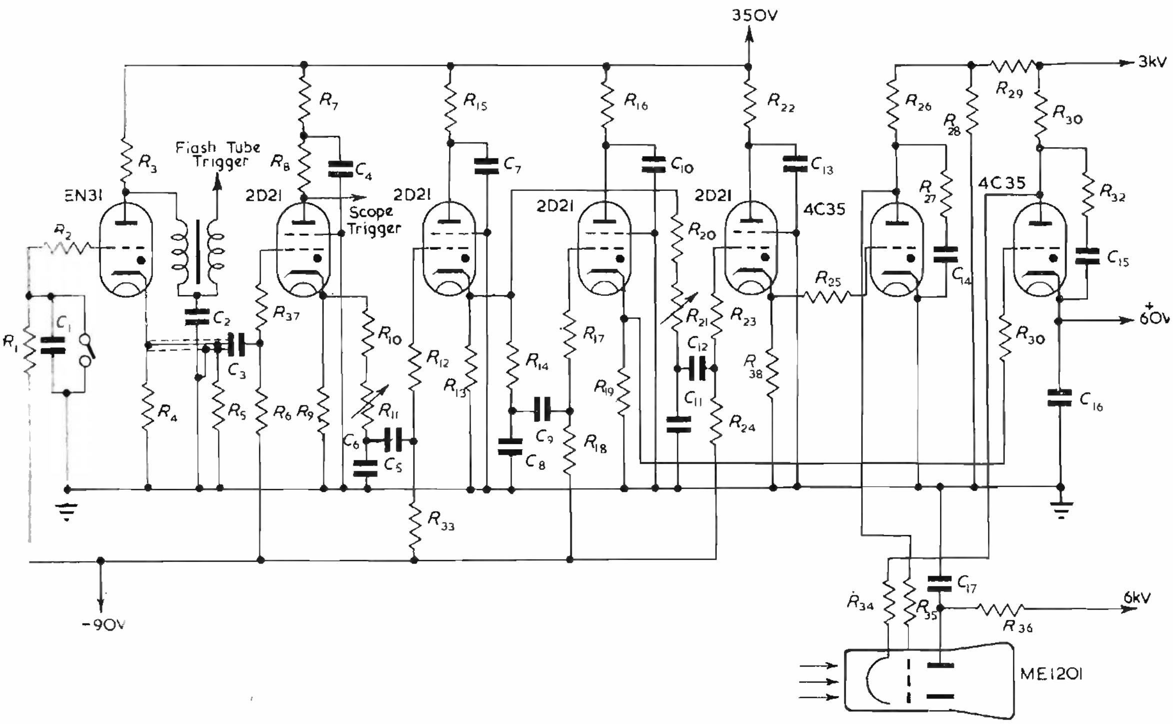


Fig. 8. Circuit diagram of the A.R.E. Camera

The shutter is opened by dropping the cathode to + 60 volts and closed again by earthing the grid, the 4C35 hydrogen thyratrons being used as switches. The EN31 is used as a trigger valve to provide a pulse from a trigger transformer to fire the flash tube. Synchronism between the flash tube and the opening of the shutter is effected by R_{11} where a delay of up to 100 microseconds can be introduced before V_3 fires. A split signal from V_3 triggers V_4 through a fixed delay integrator and V_5 via a variable integrator. The delay integrator V_5 can be made to fire just before or up to 2 microseconds after V_4. It can be seen that V_5 and V_4 trigger off the hydrogen thyratrons V_6 and V_7 respectively and so R_{21} gives an effective range of exposures of up to 2 microseconds. Using this circuit exposures of 5×10^{-8} second can be taken of non self luminous objects. In the study of some self luminous phenomena, such as sparks, much shorter exposures can be made in certain cases, as the usual limit to the maximum speed is the shortage of light from the object. Fig. 9 shows a series of pictures of the discharge in an LSD.II flash tube showing the appearance of the discharge at various intervals after triggering. The exposures in each case were 10^{-7}sec duration. The absolute necessity for the aluminium backing layer on the screen can be seen when making records of this type. The shutter of the recording camera must, of course, be open during the

Fig. 9. Various stages in the discharge of an LSD2 microsecond flash tube. Exposure 10^{-7}sec using an ME1201 image convertor shutter

(1) *Static picture of tube.* (2) 1μ*sec after triggering.* (3) 2μ*sec after triggering (peak of discharge).* (4) 35μ*sec after triggering.* (5) 60μ*sec after triggering.* (6) 70-80μ*sec after triggering.*

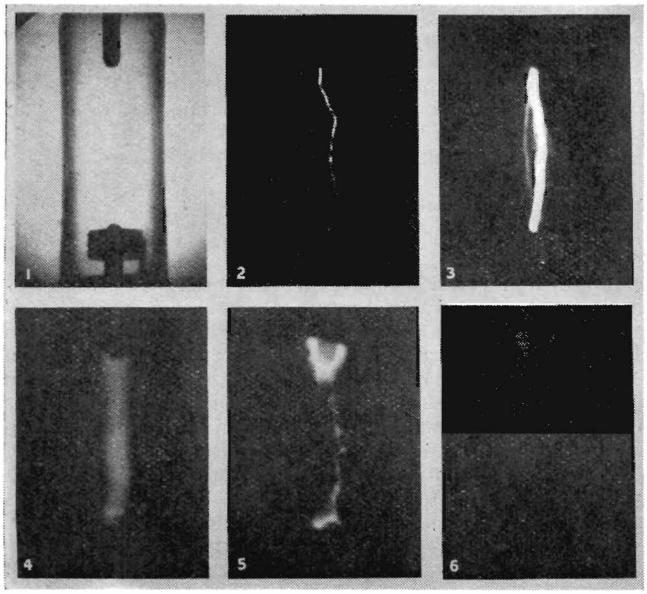
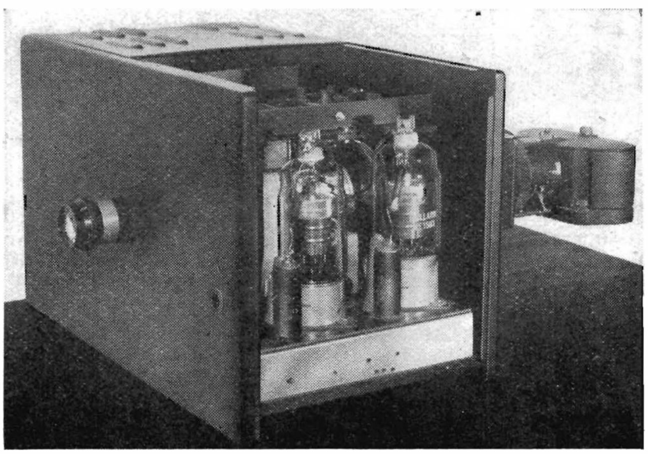


Fig. 10. High speed camera used at the Mullard Research Laboratory



whole of the flash tube discharge which is only a few microseconds long around the peak. Without the opaque layer of aluminium the screen would be brightly illuminated by light passing through the photocathode and the fluorescent image completely obliterated by the overall exposure of the film. The widest aperture lenses can be used for the very high speed applications, as standard lenses for 35mm cameras adequately cover the 30mm cathode and the Wray f/1 copying lens reduces the image from the screen on to 35mm film.

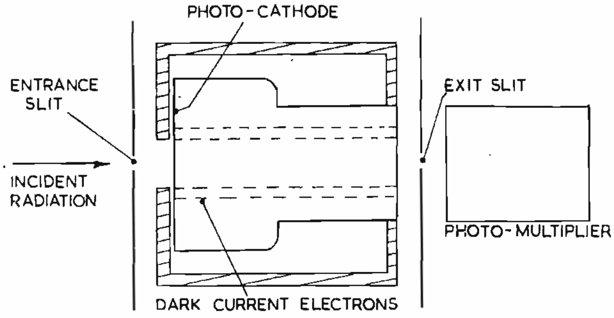


Fig. 11. The ME1202 light transformer and photomultiplier set-up

A laboratory image convertor camera is shown in Fig. 10. The photocathode image forming lens is in the centre of the front panel and the recording camera can just be seen projecting at the rear. The screen end of the image convertor is visible between the 4C35 thratrons.

The ME1201 has been successfully used as a direct viewing stroboscope[10], a frequency of 20kc/s being used with exposures of 1microsecond duration. A further application enables a limited number of discreet pictures to be recorded in succession. If only a small section of the photocathode is used, suitably phased deflecting fields can move the image into different parts of the screen for a series of short exposures.

The ME1202

This is a simple two-electrode tube whose main function is as a wavelength transformer. It has a caesium-oxygen-silver cathode and a fast decay blue phosphor, both screen and cathode being 30mm in diameter. It is mounted in a cylindrical insulating box for convenience and protection. The anode potential is 6kV and the tube is intended to operate either without focusing or totally immersed in a solenoid which gives an electron optical magnification of unity.

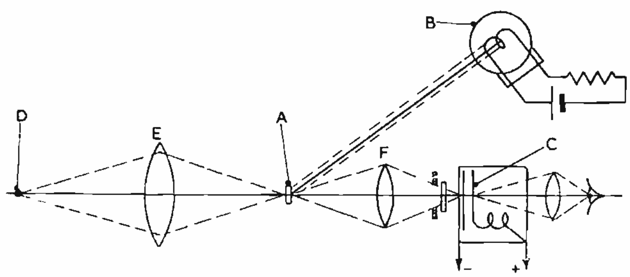


Fig. 12. An image convertor used as an optical pyrometer in the temperature range 350°C-700°C

The tube was designed to extend the range of an automatic recording absorption spectrophotometer into the infra-red region[11]. The light from the exit slit is normally picked up by a photomultiplier which has a caesium-antimony photocathode which has virtually no response above 6,500 Angstrom units. The interposition of the image convertor between the exit slit and the photomultiplier enables readings to be taken as far as $1{\cdot}1\mu$. The light source used in this application is chopped into a square waveform at 200c/s and, in order to reproduce the waveform satisfactorily, the rise and decay of the screen fluorescence must be quite rapid. In this case zinc sulphide is treated with a nickel "killer" which suppresses the afterglow.

No high gain photoelectric multipliers are at present made with red and infra-red sensitive photocathodes owing to the difficulties of high dark currents originating from thermionic emission from various electrodes in the tube. For this reason, most multipliers have spectral response curves of a type corresponding to the type "A" surface. The advantage of the use of the ME1202 is that a slit can be placed between the fluorescent screen and the photo-multiplier as shown in Fig. 11. This slit is arranged so that it only passes the image or part of the image of the entrance slit. In this way all thermionic dark current from the unused portion of the ME1202 photocathode is removed from the signal picked up by the multiplier. In this way, the dark current is reduced by a factor equal to the ratio of the areas of fluorescent screen and exit slit.

Image Convertors for Colour Television Experiments

A complete closed link television camera set up for the

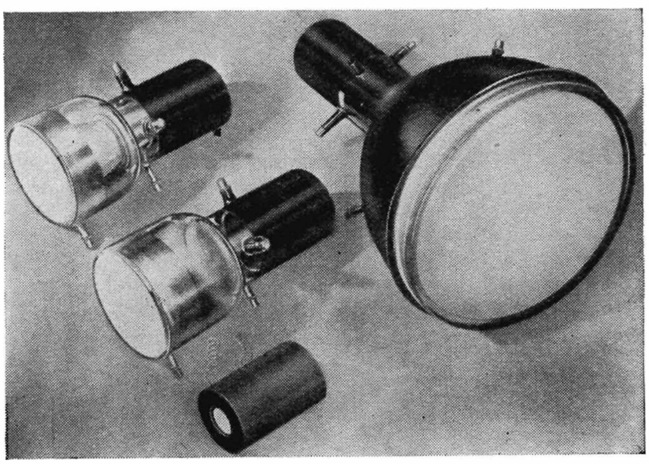


Fig. 13. A Group of Mullard Image Convertors

investigation of physiological effects in colour television is of necessity a complicated apparatus, but an image convertor with the same photocathode as a television camera tube can present directly a high definition monochrome picture of any scene on a normal white fluorescent viewing screen. The use of suitable filters should enable problems of colour rendering and flicker to be studied.

Some Uses of Infra-Red Convertors

INFRA-RED PYROMETRY

Image convertors with caesium-oxygen-silver photocathodes and green willemite screens have been used successfully in optical pyrometry. Barber and Pyatt[12], used an E.M.I. CV144 and achieved a reproducibility of from 1-2°C on measurements in the temperature range from 350° to 700°C. The optical arrangement used is shown in Fig. 12. A thin strip of white paper A sandwiched between glass plates and illuminated from the side by a lamp B takes the place of a conventional disappearing filament. The image of the strip of paper is seen on the image convertor screen C, superimposed on the background of the object D whose temperature is to be measured. Lenses E and F image the object and paper strip on to the photocathode, while a red filter improves the colour matching of source and strip. A tube of the ME1202 type can be used with advantage in this application as it does not suffer from light feedback from screen to cathode.

Photography in the Infra-Red

The use of an image convertor of the ME1200 type will enable infra-red photographs to be taken using normal high-speed emulsions, thus avoiding the use of the special sensitized infra-red emulsions which it is not always convenient to use. The picture quality recorded from the fluorescent screen will not of course compare with results obtained directly with the larger sized plate cameras, but results typical of average 35mm techniques should be possible. No comparison can as yet be given between the effective speeds of the image convertor set-up compared with infra-red film.

Control of the Processing of Light Sensitive Materials

In the preparation of photographic emulsions it is often desirable that stages in the process should be watched. For example films and plates must be inspected for flaws in the coating. This sort of work is usually carried out by the light of very faint "safelights" and the general level of illumination is so low that at least 30 minutes is needed for dark adaptation of the eye. Visual acuity is low and fine detail cannot be perceived. Even under these conditions, high-speed panchromatic emulsion must not be exposed too long without risk of fogging. The use of infra-red lighting and a suitable image convertor will enable the process to be watched on a fluorescent screen bright enough to avoid the necessity for dark adaptation of the eye.

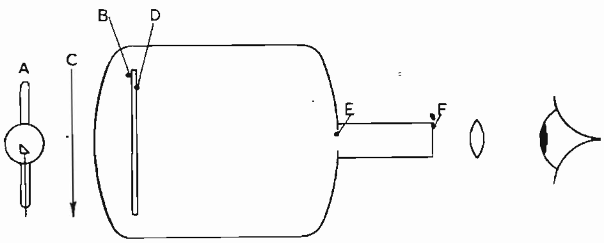


Fig. 14. The principle of the X-ray image intensifier

Brightness Intensification

The latent possibility of using image convertors as light amplifiers has long been recognized in that the raising of the energy of the photoelectrons by means of an accelerating potential implies that some of the extra energy can be recovered as light at the fluorescent screen.

If we define wattage amplification in an image convertor as the ratio of watts radiated from the fluorescent screen (neglecting heat radiation) to watts incident on the photocathode, it can be seen that this quality depends on the efficiencies of both photocathode and fluorescent screen. Using high sensitivity cathodes of the "A" type and a high efficiency zinc sulphide phosphor, quite useful wattage gains can be achieved. If now a suitable electron optical lens system is used to reduce the image size of the fluorescent screen, very large degrees of "brightness intensification" can be achieved[13, 14, 15, 16]. With a perfect optical viewing system, the small image on the fluorescent screen can be restored to its original size without loss in brightness. In the practical case there is, however, a small loss in the lens system.

Brightness intensifiers have so far been mainly considered for application to X-ray radiography, but they should prove of use in viewing any phenomena where the illumination is just below the threshold of ordinary vision. For example, tubes constructed as laboratory models have been used for viewing a cathode-ray tube trace which was completely invisible to the unaided eye.

The brighness of the fluorescent screen in direct visual X-ray examinations is usually very low. Several factors make this unavoidable especially in chest and abdominal cases. A prolonged dark adaptation of the eye is necessary and even then limitations of retinal physiology (loss of visual acuity and intensity discrimination at low light levels) render the available sharpness and contrast more or less invisible[13]. The need for an increase in brightness has long been recognized and a patent relating to an electron image-intensifier was taken out in 1942[17]. Since that date, workers in many countries have been tackling the problem and several workable intensifier tubes have been made. The principle of the X-ray intensifier is shown in Fig. 14. The X-rays from A pass through the object C and strike the fluorescent screen B laid on the inside surface of the glass end plate. The fluorescent screen is provided with a smooth back surface on which is formed a photocathode D. The exitation of the phosphor by the X-rays causes the photocathode in the immediate proximity to emit electrons and the electron lens E produces a much reduced image of the photocathode on fluorescent screen F. With a linear image reduction of the order of 5 and a screen potential of 25kV brightness gains of about 500 times can be achieved[16].

After the impetus given to techniques and design by the second world war, the use of image convertors was centred around infra-red applications. The recent interest in image convertor techniques for high-speed photography and the development of electromagnetically focused tubes of the ME1201 type giving a picture of considerably better quality than previous electrostatic tubes, has opened up new and ever widening fields of image convertor applications.

Acknowledgments

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REFERENCES

1. Epstein, D. W., and Pensak, L. Improved Cathode Ray Tubes with Metal Backed Luminescent Screens. *R.C.A. Rev.* 7, 5 (1946).
2. Pratt, T. H. An Infra-red Image Convertor Tube. *J. Sci. Inst. 24*, 31 (1947).
3. Pratt, T. H. The Infra-red Image Convertor Tube. *Electronic Engg. 20*, 274 (1948).
4. Krizek, V. and Vand, V. The Development of Infra-red Technique in Germany. *Electronic Engg. 18*, 316 (1946).
5. Langer, R. H. and Gelbaum, B. R. Report on Infra-red Telescopes Manufactured by Carl Bosch Laboratories, Berlin. *C.I.O.S. XXX*, 35 (1945).
6. Morton, G. H., and Flory, L. E. An Infra Red Image Tube. *R.C.A. Rev.* 7, 385 (1946).
7. Courtney-Pratt, J. S. A New Method for Photographic Study of Fast Transient Phenomena. *Research. 2*, 287 (1949).
8. Courtney-Pratt, J. S. A New Method for Photographic Study of Fast Transient Phenomena. *Proc. Roy. Soc. of London. 24*, 27 (1950).
9. Mitchell, J. W. Gas Filled Discharge Tubes as Light Sources for High-speed Photography. *Trans. Ill. Eng. Soc. 14*, 91 (1949).
10. S.E.R.L. Exhibit, 35th Phys. Soc. Exhibition, 1951.
11. Holiday, E. R. and Wild, W. An Image Convertor to Extend the Useful Range of Photomultipliers to Larger Wavelengths. *J. Sci. Inst. 28*, 282 (1951).
12. Barber, C. R. and Pyatt, E. C. An Optical Pyrometer Employing an Image Convertor Tube for Use Over the Temperature Range 350-700° C. *J. Sci. Inst, 27*, 4 (1950).
13. Chamberlain, W. E. Fluoroscopes and Fluoroscopy. *Radiology. 28*, 283 (1942).
14. Morton, Ruedy and Krieger. The Brightness Intensifier. *R.C.A. Rev. 9*, 419 (1948).
15. Coltman, J. W. Fluoroscopic Image Brightening by Electric Means. *Radiology. 51*, 359 (1948).
16. X-ray Image Amplifiers. *Rev. Sci. Inst. 19*, 477 (1948).
17. U.S. Patent No. 2,270,373.

A Method of Measuring Television Picture Detail

By G. G. Gouriet,* A.M.I.E.E.

A measurable quantity "picture detail" is defined, which affords the means of measuring objectively the amount of detail in a television picture. Apparatus suitable for measuring "picture detail" is described and finally various applications of the apparatus† are suggested.

Of the various factors which contribute to the overall quality of a television picture, there is little doubt that picture definition is one of the most important. Furthermore, it is this factor which is frequently degraded when one or more elements of the overall transmission system are faulty or out of adjustment. The performance of the electrical elements may be checked by measuring either the steady state or transient response, but such measurements are of a relatively complicated nature and can only be undertaken outside the hours of transmission. The optical and electro-optical characteristics can be conveniently measured only in a laboratory, and when equipment is once in service adjustments are usually made on a purely subjective basis, and this often leads to errors which are cumulative. Thus, an operator who is using an electronic viewfinder, in order to adjust the optical focus of a camera, will find it difficult to decide upon the precise position of focus if any of the electro-optical elements of the camera are incorrectly adjusted. The reverse is also true. In either case the position of optimum focus will not have changed but it will be difficult to detect with accuracy merely by looking at the television image.

A further difficulty arises if during, or immediately prior to, transmission, it is required to compare the quality of the picture received at a remote point with that of the picture at the source. Even if a test card is used for the purpose, such a comparison will normally depend upon the subjective assessments of two observers and will therefore of necessity be only qualitative.

If picture definition is to be maintained at a consistently high standard, it is obvious that an objective method of measurement is essential. This article proposes a method by which a defined factor termed "picture detail" may be measured objectively, and describes briefly the design of apparatus suitable for making the measurement, together with some of the possible applications.

The Picture Detail Factor

Before considering methods of measurement it is first necessary to define the quantity to be measured. There are, of course, a number of possible ways in which "picture detail" could be defined as a measurable quantity. For example, consider the simple case of a picture with only two levels of brightness, say black and white. The detail along any arbitrary line drawn across the picture, i.e. a single line of scan, could be defined as the number of transitions from black to white and white to black. On this basis the overall picture detail would be the sum of all the transitions counted along the total number of scanning lines which were required to complete the picture. It is apparent that for a system capable of resolving a maximum of N elements in both horizontal and vertical directions, the most complicated picture would never exceed N^2 transitions and would comprise a picture element chequerboard. Since relative rather than absolute measurements are of interest, the factor could conveniently be normalized by dividing by N^2 so that the chequerboard would have a detail factor of unity and less complicated scenes an appropriate fraction.

For a picture involving a continuous range of grey tones, the situation is a little more complicated. Here, a possible choice would be to define the detail along a single scanning line in terms of the number of times that the slope of the function expressing the variation of brightness changed sign. This would in effect be counting all transitions as being of maximum amplitude and would therefore agree with the previous definition in the case of a two-tone picture.

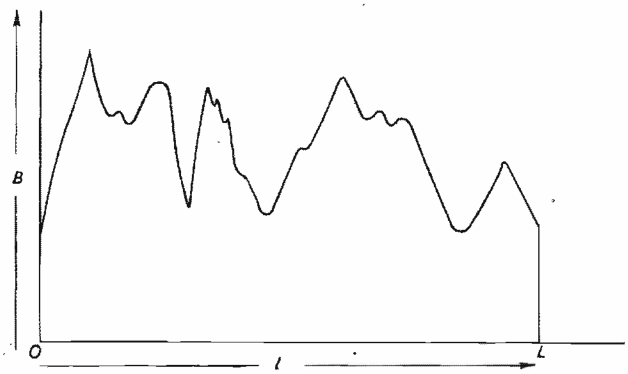


Fig. 1. Curve of brightness in the direction of scan plotted as a function of distance

While this latter definition has certain advantages it does not take account of the amplitude with which detail is resolved, and in practice this would be a serious disadvantage. The finest detail may still be present when a picture is defocused, but the fact that the contrast is reduced in the regions of fine detail cannot be discounted.

In order to take account of both the number of transitions and the various amplitudes, the following most general definition is proposed:

"The 'picture detail' over a given length of scan shall be defined as the modulus slope of the brightness variation integrated over that length."

In mathematical form:

$$D = \int_0^L |dB/dl| \, dl \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where D = picture detail over length of scan L.
B = brightness as a function of scanning length l.

This definition has a simple physical interpretation. If the brightness B along the length of scan L is plotted as a function of distance, as in Fig. 1, then D is the sum of all displacements of the curve projected on the B axis. The relationship between this function and the commonsense

* *British Broadcasting Corporation.*
† *This apparatus is the subject of British Patent Application No. 14810/52*

view of picture detail may be illustrated by considering a picture composed of picture elements of the size of the finest detail. Proceeding from one element to the next along a scanning line and noting the change in brightness between elements irrespective of sign, it would be reasonable to argue that if no change occurs no detail is present, while a change of maximum amplitude would represent a single contribution of maximum detail. With intermediate values of brightness change weighted accordingly, the total detail will thus be the sum of the modulus of the individual changes, which in the limit for vanishingly small elements is given by Equation (1).

For the purpose of measurement we shall be concerned with the electrical waveform which results from scanning the image with a constant velocity of scan, v_s. Assuming for the moment a linear light/voltage transfer characteristic, we may replace the brightness B with a proportional voltage e, and putting $l = v_s t$ and $L = v_s T_s$, where T_s = duration of scan, we obtain

$$D = \int_0^{T_s} |de/dt| \, dt \quad \ldots\ldots\ldots\ldots (2)$$

as a measure of detail referred to the time function.

Design of Measuring Apparatus

The electrical analogue of Equation (3) is very straightforward. If the television picture waveform is applied to a simple differentiating circuit and then to a linear full-wave rectifier, the resulting signal will be of the form

$$\mu\tau \, |de/dt| \quad \ldots\ldots\ldots\ldots (5)$$

where μ is the circuit gain and τ is a constant with the dimension of time, e.g. CR or L/R. The average value of this signal over a period T_s is

$$\mu\tau/T_s \int_0^{T_s} |de/dt| \, dt \quad \ldots\ldots\ldots\ldots (6)$$

and for a still picture, this is simply the D.C. component which may be measured directly on a suitable D.C. meter.

On comparison, Equation (6) will be seen to be of identical form to Equation (3) and will provide an exact measurement of D_F if μ is adjusted suitably. The measurement may also be carried out on a moving picture, since changes in picture detail do not normally occur at a rate comparable with the picture repetition rate.

The block schematic of Fig. 2 shows the main elements which are incorporated in the design of a complete detail meter. The diagram is largely self-explanatory and only the more interesting features will be referred to. Differentiation is carried out by means of an inductance in the cathode circuit of a cathode-follower, the impedance being raised by the addition of a suitable resistor. At the highest frequency the reactance of the inductance is sufficiently small when compared with the resistor to ensure accurate differentiation over the required band of frequencies. A phase-splitter provides a balanced signal which is rectified by a full-wave bridge rectifier, the output of which is measured on a D.C. meter with a 0·1mA movement, calibrated 0-100 per cent.

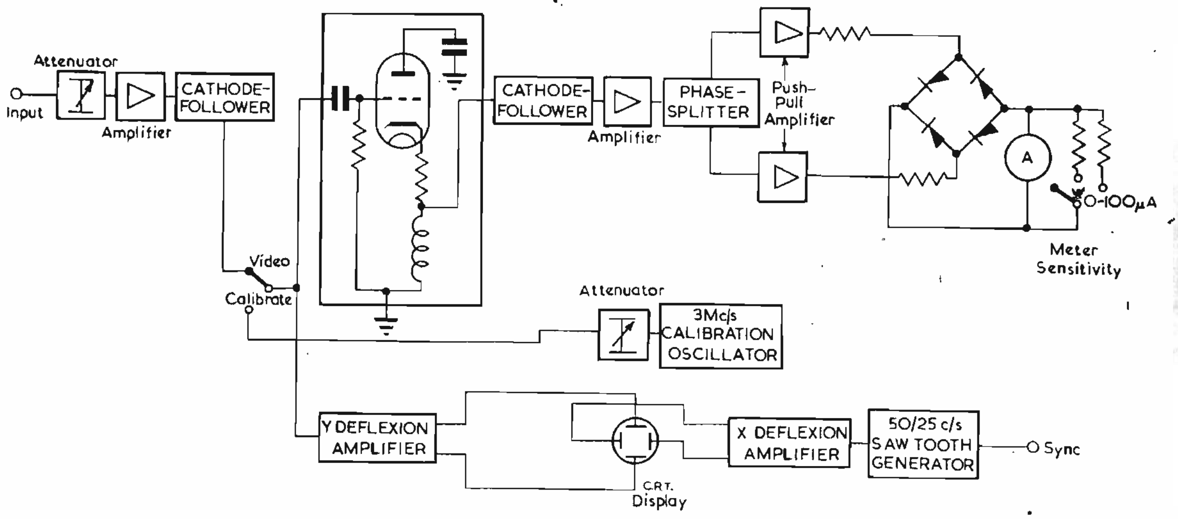


Fig. 2. Simplified block schematic of picture detail meter

Finally, for relative measurements, we require to define a dimension-less quantity, "picture detail factor", which will have a value of unity for a picture element chequerboard. Let D_m be the maximum value of D corresponding with the picture element chequerboard; then the detail factor

$$D_F = 1/D_m \int_0^{T_s} |de/dt| \, dt \quad \ldots\ldots\ldots\ldots (3)$$

The actual value and dimensions of D_m are perhaps of academic interest. Consider the waveform corresponding with a picture-element chequerboard containing a total of N^2 elements. Since the picture repetition rate is $1/T_s$ the number of elements per second will be N^2/T_s. If the peak amplitude of the waveform is E then each picture element will produce a voltage excursion of E and the total value of D_m will thus be EN^2/T_s volts/sec. Since the bandwidth Δf required to transmit such a pattern (neglecting synchronizing signals) is $N^2/2T_s$, we may write

$$D_m = 2E\Delta f \text{ volts/sec} \quad \ldots\ldots\ldots\ldots (4)$$

In practice this is of little interest since it merely represents a scale factor which is introduced in the process of calibration.

A 3Mc/s oscillator is incorporated to provide a calibrating signal. This corresponds to the signal which would result from an ideal camera viewing a picture element chequerboard, except that frame and line suppression signals are not included in the calibration signal. The measured value of D_m for the calibration signal is thus approximately 20 per cent greater than is actually required, but it is simpler to allow for the discrepancy than to include suppression signals in the design. If the oscillator frequency is reduced by 20 per cent, the effect upon the value of D_F will be the same as if suppression signals had been added.

Calibration is carried out using a 4-inch C.R.T.

incorporated in the instrument. With the calibration switch at CAL the calibration attenuator is adjusted until the meter reads 100 per cent, the peak-to-peak amplitude being noted on the C.R.T. With the switch at VIDEO, the picture signal level is then adjusted so that the black-level to peak-white amplitude equals the peak-to-peak amplitude of the calibration signal. The value of D_F is then observed directly on the meter as a percentage. The sensitivity of the meter is adjustable so that small values of D_F may be measured accurately.

Results of Preliminary Tests

An experimental picture detail meter as described above has been constructed and used for some preliminary observations. As a means of ensuring that the apparatus was performing correctly, various tests were carried out, one of which was to mask off areas of a regular pattern used as a scene and to note that the value of D_F fell in proportion to the masked area.

The "picture detail factor" of various scenes was measured using normal types of studio camera and also a 35mm flying-spot film scanner. The film scanner was known to be capable of producing the full depth of modulation up to the video frequency limit of 3Mc/s, while a typical camera produced 50 per cent modulation at 3Mc/s.

Over a wide variety of typical scenes the average value of D_F using a camera was found to be 1·8 per cent. The greatest value of D_F, namely 2·4 per cent, was obtained with a high quality photographic transparency depicting an elaborately furnished interior containing a considerable amount of fine detail of high contrast ratio.

The film scanner gave a maximum value of 8 per cent on one particular scene comprising the faces of spectators in a packed grand-stand at a sports stadium. In general, the value of D_F rarely exceeded 5 per cent.

These figures indicate the extent to which bandwidth compression might be effective if a suitable means of signal coding were devised.

Further experiments were carried out in order to examine the accuracy with which various focus controls could be adjusted, observing the maximum value of D_F as the criterion of focus. The tests indicated that a more precise focus was obtained by adjusting in this manner than was possible when viewing a picture monitor.

It is interesting to note that a very definite maximum value of D_F is found to exist when a lens iris is adjusted through its range. As the lens aperture is reduced, the value of D_F increases because of the increased depths of focus until the point is reached where the reduction of light more than off-sets the increase of detail. In all cases it appeared that the maximum value of D_F was consistent with the most acceptable picture.

Errors Arising in Measurement

EFFECT OF SYNCHRONIZING SIGNALS

When carrying out a measurement it is usually convenient to use the complete vision waveform, which includes synchronizing signals, and since the synchronizing signals are not contributing to picture detail, an error exists. For relative measurements, this error is of little importance, but it is nevertheless worth noting its magnitude. Assuming a 70:30 picture to synchronizing ratio, each line will contain two spurious excursions of the waveform, each nearly 50 per cent of the peak picture amplitude. Each line will therefore contain one element-worth of spurious signal. Since a line contains roughly 500 elements, the error is thus 0·2 per cent in the case of the ideal chequerboard. The value of D_F for the synchronizing signals alone is thus approximately 0·2 per cent, and in the case of a picture for which $D_F = 2{\cdot}0$ per cent the error would thus be 10 per cent.

However, the synchronizing signals may easily be accounted for in the calibration process. Since the unwanted excursions are added linearly, it is permissible to adjust the meter to read zero while the picture is uniform grey, and the error is thus eliminated.

ERROR DUE TO NOISE

The picture signal will normally be accompanied by either a flat or triangular noise spectrum, depending on the type of pick-up device in use. In either case the value of D_F for the noise signal will be large, since the noise is present for all of the time. A noise level of −25db on peak white will produce a value of D_F similar to that of the picture signal and a substantial error is thus introduced. However, this too may be eliminated by setting the zero of the meter on a blank scene, although here the procedure requires some justification, since the values of D_F for noise and picture measured separately will not, strictly speaking, add linearly when measured together. Consider a picture which is itself purely random in light distribution; it will have the same form as noise, and noise would thus add to it on a power basis. However, a real scene is not random and has plain areas which must be predominating if the value of D_F is only a few per cent. In all the plain areas, the linear addition of detail relating to noise and signal must apply, since the picture detail is zero. This must also be approximately true when the picture waveform is changing gradually. So long as the value of D_F for the picture is only a few per cent it is therefore justifiable to subtract the noise reading from the picture-plus-noise reading. For very large values of D_F (if they were ever obtained) this would not be permissible, but the error due to noise would then be small.

THE EFFECT OF CONTRAST LAW

Earlier it was assumed that the signal voltage e was a linear function of the brightness B. In most instances this will not be true, but it will be of little importance when relative measurements are being taken on a given pick-up device. However, if the resolving power of one system is being compared with that of another, the output signal of each system should in general be modified with a non-linear network of transfer characteristic similar to that of the viewing tube which would normally be used. However, in the particular case of a scene in which detail was distributed equally throughout the contrast range, this would not be necessary since the value of D_F would then be independent of the contrast law. Any reduction of slope at one level would be compensated by the increase in slope at another.

By noting whether or not a change of contrast law affected the value of D_F, and in what manner, it is thus possible to establish whether detail is predominant in either the light or dark areas of a scene.

Practical Applications

SERVICE MONITORING

The most obvious practical application of a picture detail meter is the monitoring of the television waveform at the various terminal points of a broadcasting system. Thus a standard test card may be used at the programme source and a limit set to the minimum value of detail consistent with a satisfactory standard of resolution. Measurement of the detail factor in simultaneous broadcasting centres should assist materially in checking and monitoring the performance of link equipment.

Where apparatus is designed with a remote focusing facility, usually a fine adjustment, this may be carried out on an objective basis if a detail meter is used.

PERFORMANCE COMPARISON OF PICTURE PRODUCING EQUIPMENT

Previously the results of measurements obtained from a studio camera and a flying-spot film scanner were compared. Similarly measurements may be compared using different types of camera tube, or different processes such as those involved in television recording or standards conversion. This may prove particularly useful during the development of apparatus when it is required to measure small changes in performance due to changes in design.

In this connexion it is perhaps of interest to note that the measurement of picture detail affords a rapid means of taking an overall frequency response curve of a complete system including the optics. Charts of fixed size comprising varying numbers of vertical lines per unit length may be used in succession as a test object, commencing with the coarsest patterns. Provided that the system under test is fully resolving the patterns, the detail factor will rise linearly with the number of vertical lines in the test object. At the point where the overall response is falling at 6db per octave the curve of detail factor plotted against number of lines will have zero slope and thereafter will assume a negative slope. Typical curves that apply to a camera with and without aperture correction are shown in Fig. 3.

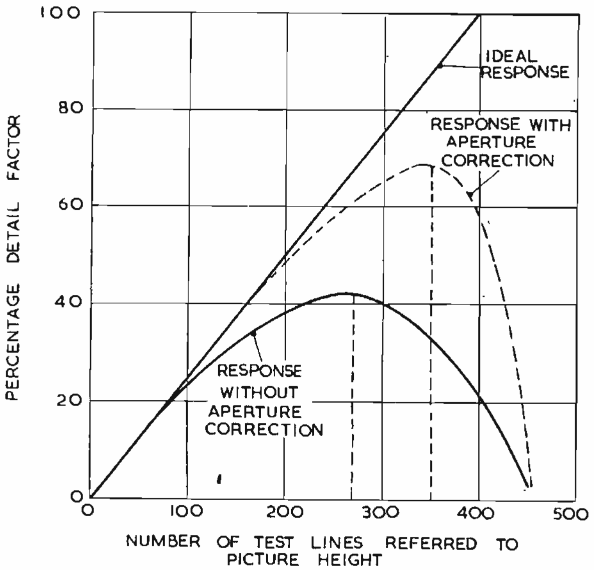


Fig. 3. Detail response curves obtained for camera with and without aperture correction

The number of grating pattern lines corresponding with the maximum value of the curve so obtained might be considered useful to quote as a single figure of merit, since beyond this point the law of diminishing returns would seemingly apply. The response curve proper may be obtained by subtracting from unity the difference between the linear curve representing the ideal response and the measured curve.

Automatic Focusing

Automatic focusing is not likely to be a practicable proposition in cases where a scene has depth, for the obvious reason that the plane which offers the greatest detail is not necessarily the plane on which it is required to focus. However, for certain apparatus where the object plane is fixed, such as for a film scanner or a standards convertor, automatic focusing would be quite straightforward. It would be necessary to introduce a small degree of "hunt" in order to determine sense, but this would not need to be of sufficient magnitude to be detectable as a variation of focus on the received picture.

Conclusion

It is at present early to forecast the extent to which picture detail measurements by the method suggested will be useful. Furthermore, alternative definitions pertaining to similar measurable quantities may prove to be more apt. However, there is little doubt that in the field of television, there is a considerable need for a method of measuring picture definition, defined as an objective parameter, and the purpose of this article has been to suggest one possible method. Apart from the applications which have been discussed, there is also the application for which the definition and measurement of "picture detail" was first conceived, namely, as a method of studying the statistical structure of television pictures in connexion with the possible application of Information Theory to television.

Acknowledgments

The author would like to thank the Chief Engineer of the British Broadcasting Corporation for his permission to publish the information contained in this article.

He also wishes to express his appreciation of the assistance given to him by his colleagues in the BBC Research Department.

A 15 MeV Linear Accelerator for Harwell

A 15MeV linear electron accelerator is now completing its final tests in the Mullard Research Laboratories under the direction of Dr. C. F. Bareford. This machine will soon be transferred to the Atomic Energy Research Establishment at Harwell where, in association with a neutron time-of-flight spectrometer built simultaneously in the same laboratories, it will be used to carry out measurements which will greatly assist in the design of nuclear reactors for the industrial utilization of atomic power.

This machine is based on work originally carried out by D. W. Fry and his collaborators in T.R.E. and A.E.R.E. of the Ministry of Supply. It has been developed by a team of Mullard physicists and engineers led by M. G. Kelliher on behalf of Philips Electrical Ltd., under a contract sponsored by the Ministry of Supply. It has a distinct advantage over other electron accelerating machines in that it is capable of providing a vast quantity of neutrons in pulses of extremely short duration.

The principle of operation of the machine is basically as follows. A magnetron produces a succession of high energy bursts of short radio waves. These waves are used to accelerate a beam of electrons down a specially designed waveguide. This is loaded to make a corrugated waveguide so that the electrons are caused to travel with the waves and extract energy from them. The electrons enter the waveguide, which is 20ft long, at low velocity, and they leave it with a velocity of 99·95 per cent that of light.

When these very fast electrons are stopped suddenly by a heavy metal target they produce very hard X or gamma rays. When these gamma rays fall in turn on a further target a large quantity of neutrons is produced.

Since the power from the magnetron occurs in 2 microsecond bursts the electrons, gamma radiations and neutrons are produced in similar bursts. It is these short intense neutron bursts which are of interest to the nuclear physicist for use with the neutron time-of-flight spectrometer. Thus, when a sample of a substance under investigation is placed in the neutron beam, it provides information on the ability of the sample to absorb neutrons of different energies.

The corrugated waveguide deserves special mention as it must be constructed to a very high degree of precision. The tolerance on the radial dimensions, for example, is 3/10,000th inch, while the tolerance on the whole 20ft length of the waveguide is within 30/1,000th inch.

The pressure maintained in the system is 1/1,000 millionth of an atmosphere.

Some Problems in

Audio Frequency Spectrum Analysis

(Part 2)

By S. V. Soanes,* M.A., Ph.D., Assoc.Brit.I.R.E.

PART 1 last month described some of the theoretical considerations in the design of a spectrum analyser, with particular reference to the solution of the problem of the response of a tuned circuit to a varying frequency. It was also indicated that a parallel-T feedback amplifier is exactly equivalent to a series *LCR* circuit, and so can be used for experimental verification of the theory derived on the assumption of the simpler circuit configuration. A complete analyser has been built to confirm these theories and to be available for general laboratory use.

This analyser covers a working range of 20-20,000c/s, provision being made for either linear or logarithmic frequency scales. The useful input voltage range is 1mV to 300 volts, a logarithmic amplifier being incorporated so that amplitudes can be read in decibels if required. Provision is made for varying the sweep frequency between 0·1 and 30c/s, and the selectivity of the analysing filter can be varied between 10c/s and 500c/s bandwidth. The apparatus is built on six rack-mounted chassis, the display being a long persistance 12-in. cathode-ray tube (P7 screen) mounted at an angle for easy viewing.

General Arrangement

The block diagram (Fig. 3) is seen to follow the conventional superheterodyne circuit. Double conversion is employed to obtain the required minimum bandwidth, but careful choice of the intermediate frequencies is necessary for the best results.

The first I.F. must be higher than the maximum input frequency (or harmonic) likely to be applied, which may be of the order of 30-40kc/s; it should be as low as possible in the interests of stability. The frequency selected is 50kc/s.

The second I.F. must be at a lower frequency since a bandwidth of 10c/s would be almost impossible to obtain at 50kc/s, representing a Q of 5,000. The second I.F. is therefore fixed at 1kc/s, which is greater than the maximum bandwidth required (500c/s) but low enough to make the necessary Q easily obtainable.

In each case, there are two possible choices for the local oscillator frequency. The first oscillator can be placed at 50kc/s plus or minus the signal frequency. The lower frequency allows better oscillator stability, but the sweep range is a larger percentage of the frequency and linearity might be impaired. The higher frequency allows improved linearity, and also avoids the possibility of spurious responses due to oscillator harmonics. Consequently the first oscillator frequency has been chosen in the range 50-70kc/s.

The second local oscillator can operate at either 49 or 51kc/s. The image response (if not completely neutralized) is less objectionable in the first case, as it will appear on the low frequency side of the main indication when viewed on a C.R.T. display. As a result it will not interfere with the observations of lower amplitude harmonics. For frequencies of less than 2kc/s, the image will not appear on the display at all. Therefore the lower frequency was chosen for the second local oscillator.

Modulator-Oscillator Unit (Fig. 4)

The input is applied through an attenuator (P_{601}, S_{601}) to the grid of a phase-splitter, (V_{601}), the attenuator being used to reduce the input to not more than 1·5 volts peak, below which level the distortion and spurious responses are negligible.

This phase-splitter feeds a balanced modulator (V_{602-3}) which is used to allow suppression of the oscillator frequency. Otherwise when the first local oscillator (V_{604-5}) reaches 50kc/s, its output would feed directly into the I.F. amplifier, making the measurement of low frequencies impossible. Careful balancing of the modulator (P_{603} and L_{601}) is usually necessary, however, if complete suppression is desired. The linear modulator characteristic and the relatively high amplitude of the oscillator signal ensure

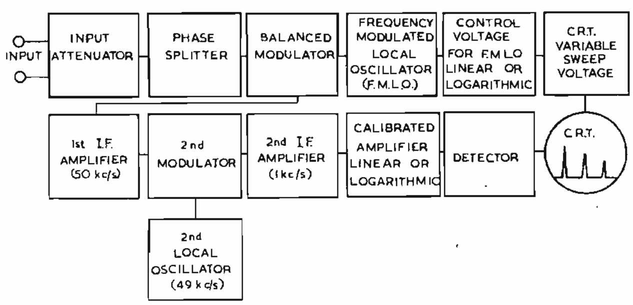


Fig. 3. Block Diagram of the Audio Frequency Spectrum Analyser

that the beat frequency output is proportional to the signal input and independent of the oscillator signal amplitude. This is true of any linear detector.

An *RC* tuned local oscillator is used, the frequency variation being obtained by varying the parallel resistance element of a Wien network.[13] The frequency of operation is proportional to $1/R^{\frac{1}{2}}$, and the resistance must therefore be varied so that it is proportional to the reciprocal of the square of the sweep voltage.

For a linear sweep, the oscillator is controlled directly from the output of the time-base generator in unit 3, Fig. 7, the only difficulty being the provision of adequate coupling time-constants. This is overcome by the use of electrolytic capacitors. It can be shown that for sweeps lasting up to 10 seconds, the departure from linearity will not exceed 2 per cent if the time-constant is greater than 200 seconds.

V_{608} derives a balanced control signal from the unbalanced sweep input, and is directly coupled to V_{606}. The cathodes of V_{606} are connected to the two diodes of V_{607} in series so that the voltage between the cathodes biases the diodes. The centre of the diode pair will be at a substantially constant D.C. level, and is connected to the grid of the first valve in the oscillator circuit, V_{604}. The impedance presented by the diodes will vary according to the applied bias,

* *Ferranti Electric Ltd., Toronto, Canada.*

the variation following a square law (at low voltages). The relation between control voltage and frequency is extremely linear from 40 to 80kc/s, and the output amplitude does not vary by more than 10 per cent over the whole useful frequency range.[14]

While a linear frequency scale is more useful for harmonic analysis, a logarithmic scale is sometimes desired. Such a scale can be produced by controlling the oscillator from a sweep voltage of exponential form. The scanning action of the cathode-ray tube remains linear with respect to time, so that the brilliance of the trace is constant. The of the spectrum, as otherwise a positive exponential voltage function would be required).

The exponential sweep is derived as follows: V_{610} is normally cut-off because of the bias developed across R_{653}. C_{621} will then charge exponentially. However, the linear sweep signal is differentiated at the grid of V_{611}; the resulting short pulse is inverted and amplified in V_{611}, and aplied to V_{610}, driving the grid positive so that the capacitor is rapidly discharged. The voltage across the capacitor is applied to a cathode-follower which feeds the oscillator control circuit (V_{609}).

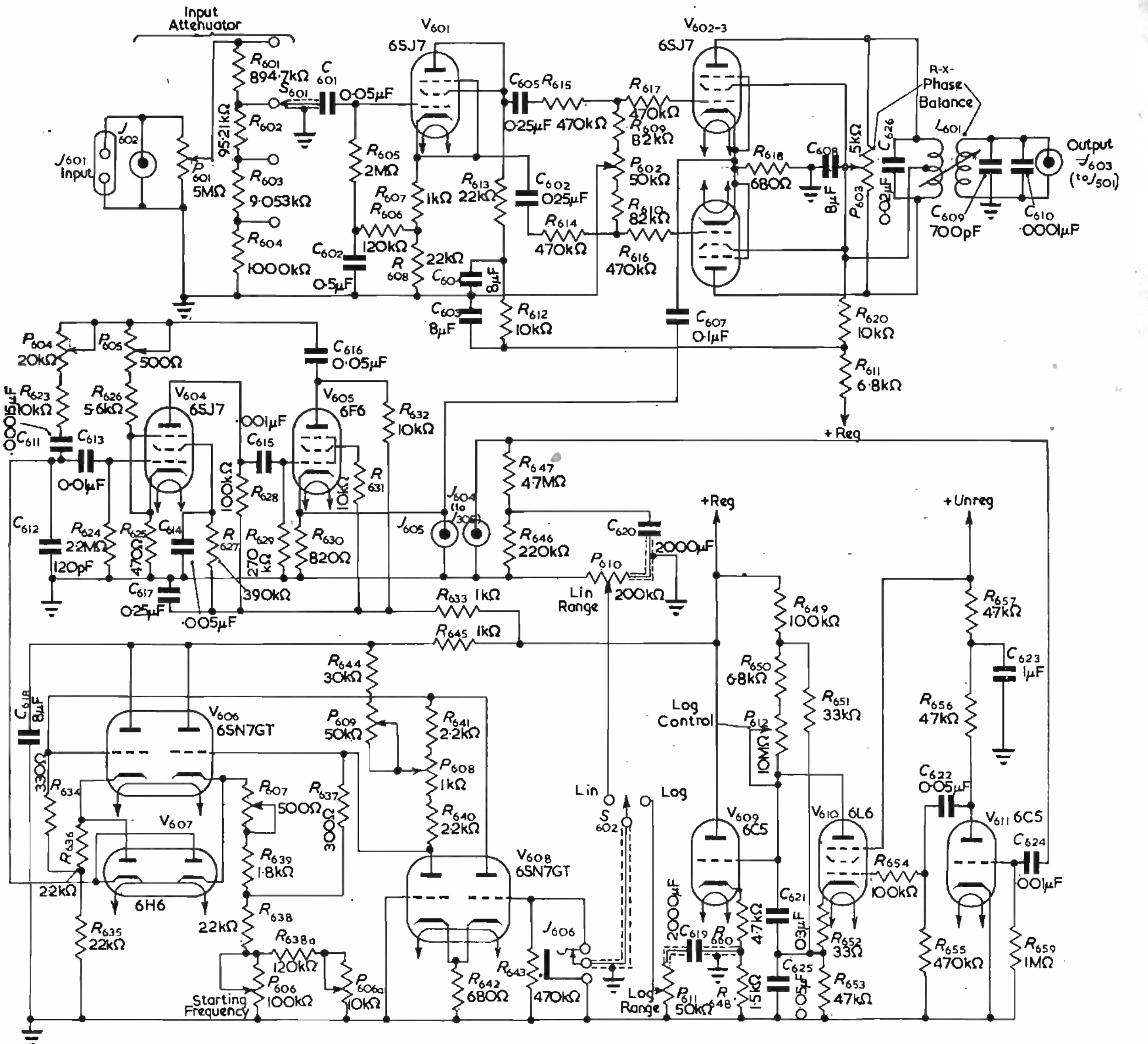


Fig. 4. Chassis No. 6—Modulator and Oscillator

sweep voltage can be represented by the following equation:

$$E(t) = A - Bf_o \; . \; 10^n \; . \; 10^{-nt/T}$$

where A, B are constants,

f_o is the lowest frequency on the scale,

n is the number of frequency decades (i.e. highest frequency in the scale will be $f_o \times 10^n$),

T is the duration of each scan.

(Note that it is necessary to start at the high frequency end

I.F. Amplifier Unit (Fig. 5)

The selective circuits in this unit are based on parallel-T networks. The elementary theory of such an arrangement was referred to in Part 1. In the present case the 50kc/s amplifier (V_{501}) uses the simple single valve circuit, but in the 1kc/s amplifier the network is very asymmetric for increased selectivity, and so requires a cathode-follower feed. P_{510} allows for variable selectivity by controlling the amount of feedback.

As the selectivity of the 50kc/s amplifier is not sufficient to reject the 48kc/s image frequency completely, a separate rejector circuit is used. In this, the output of a two-valve selective amplifier (V_{502-3}) is balanced against the original input voltage. At the frequency for which the amplifier output is maximum, the two signals are arranged to balance out exactly. At other frequencies the amplifier gain is small and the attenuation is negligible.

The second local oscillator frequency never approaches the pass-band of the subsequent I.F. amplifier, and the

Amplifier Unit (Fig. 6)

The unit amplifies the 1kc/s signal, linear or logarithmic amplification being available. The linear channel (V_{401}, V_{406}) needs no comment.

The logarithmic amplifier gives an output which is proportional to the logarithm of the ratio of the input voltage to a given reference level, and is calibrated in terms of decibels above this reference level. The amplifier com-

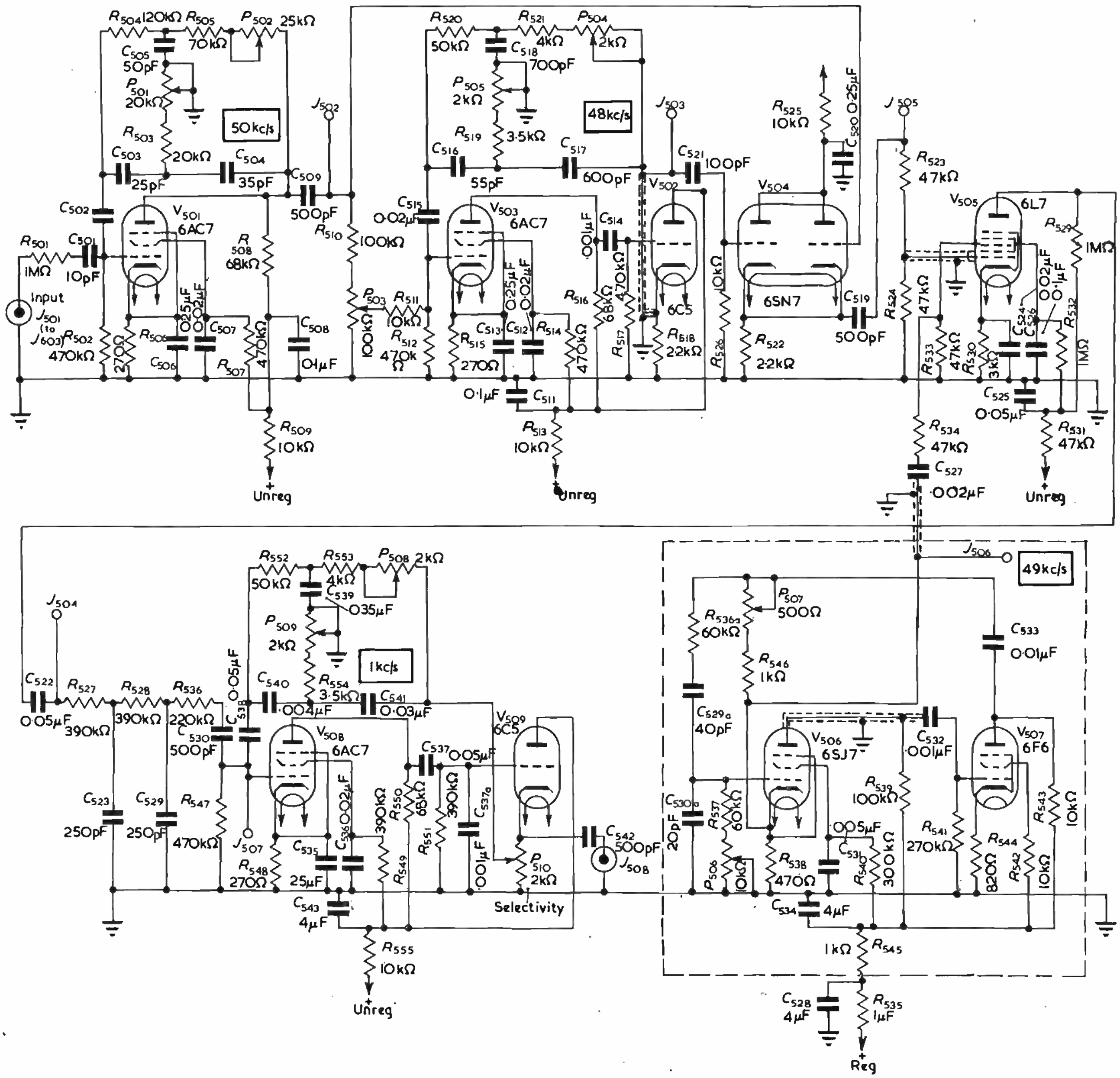


Fig. 5. Chassis No. 5—I.F. Amplifier

second modulator need not be of the balanced type. A simple circuit is used, with a Wien type local oscillator. All oscillator and modulator valves are operated with D.C. heater supplies to reduce hum and frequency modulation.

It should be noted that the 50kc/s amplifier contributes virtually nothing to the overall selectivity, except that it helps to make the selectivity curve more symmetrical for large bandwidths. It also attentuates any 1kc/s signal which might appear at the input, and which would otherwise cause a spurious response.

prises three stages (V_{402-4}), followed by a detector (V_{405}) which provides an A.V.C. bias for the first two stages. When the circuit is properly adjusted, the output voltage is proportional to the input decibels over a range of 60db, an output of 27 volts being obtained with an input of 2mV. The output is taken through a diode (V_{405}) biased to 27 volts, so that smaller signals cannot pass.

The reference level for the decibel scale can be adjusted between -10 and $+110$db (relative to 1 millivolt) in steps of 10db by use of the attenuator switches S_{401} and S_{601}.

The full screen deflexion in decibels can be set by S_{403}.

It should be noted that the overall response of such a system is different from the usual "logarithmic" amplifier in that signals of lower amplitude than 0db cannot appear on the display, which is then linear in decibels over its complete range. The amplifier described has a relatively long time-constant and is not used when making rapid analysis.

The frequency of the signal applied to the detector immediately preceding the deflexion amplifiers should be as high as possible to permit the use of a low time-constant after the detector. The amplifier output is therefore passed to a frequency doubler (V_{408-9}).

Display Unit (Fig. 7)

The cathode-ray tube is a 12HP7, which has a 12 inch screen and electrostatic focus and deflexion. The phosphor used in this tube produces a yellow long persistence light circuit being all that is necessary to produce a sufficiently linear waveform.

Power Supplies

Two chassis are used for the power supplies, one being devoted to the 1,300V 600mA supply for the deflexion amplifiers and the time-base. The other supplies A.C. and D.C. heater voltages, (6·3V at 18 amp.), regulated and unregulated H.T. (250mA), and 4kV E.H.T. for the cathode-ray tube. All circuits are conventional and are not given here.

Performance

When measuring harmonic distortion, it is important that the equipment used should introduce very little distortion itself. With two signals at 6 and 8kc/s applied to the input through separate 100,000 ohm resistors, the amplitude of each signal being 2V R.M.S. at the grid of V_{601}, the intermodulation frequencies were more than 50db below the two

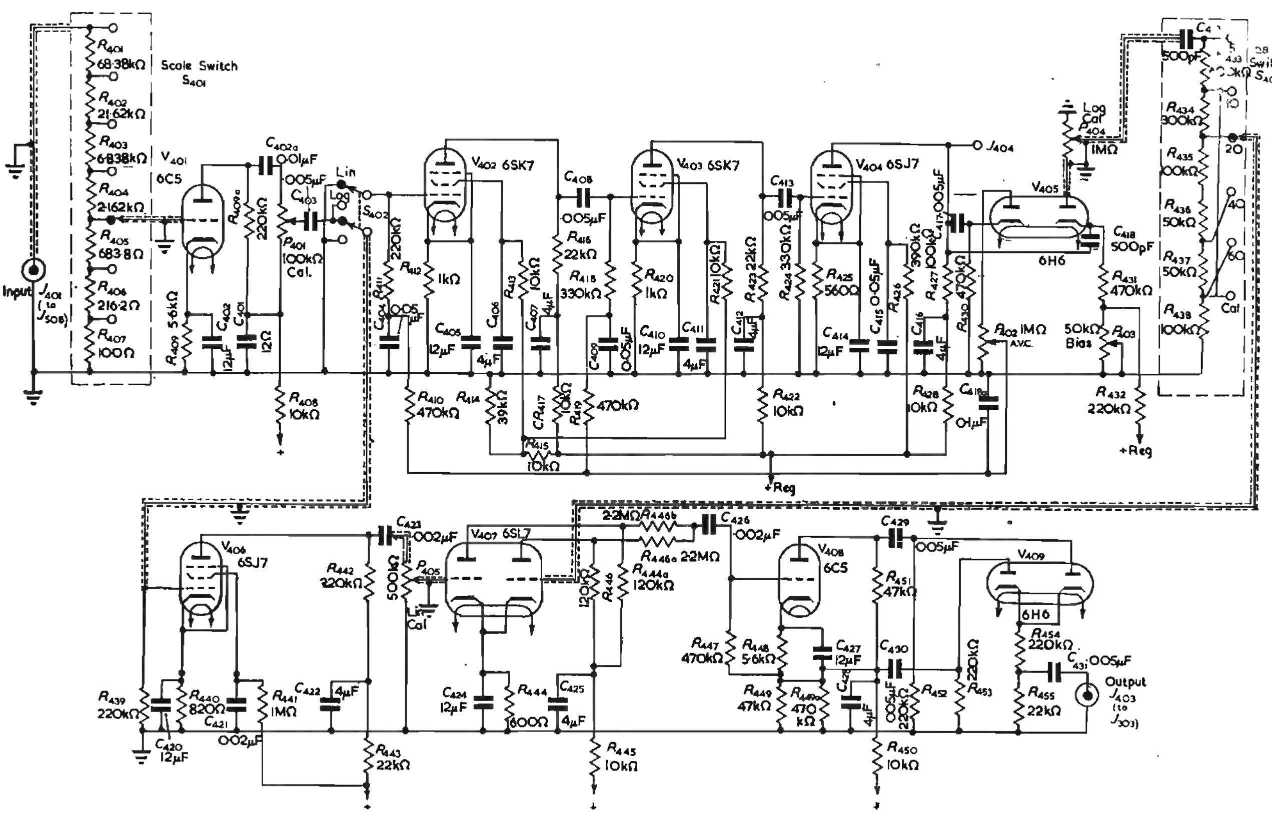


Fig. 6. Chassis No. 4—Amplifier Calibration Circuits and Logarithmic Amplifier

and also a blue short persistence light. Since the latter is somewhat objectionable when the screen must be viewed for long periods, an amber colour filter is used, which removes the blue almost completely.

Owing to the low frequencies involved, especially in the sweep circuit, direct coupling between the deflexion amplifiers and the deflexion plates must be used. Each amplifier uses two 807's (V_{310-3}) in a cathode-coupled circuit.

The vertical amplifier channel comprises a single-ended stage (V_{307}) followed by a phase-splitter (V_{307}) feeding a paraphase amplifier (V_{308}). The latter feeds a balanced infinite impedance detector (V_{307-9}). The effective frequency at this output point is therefore 4kc/s.

The sweep generator (V_{305-6}) provides a linear sawtooth signal at frequencies between 0·1 and 30c/s, the amplitude required being of the order of 20 volts. Advantage is taken of the presence of a 1,300 volt supply, a simple *RC* charging volt level. With 1 volt R.M.S. at 3·5kc/s applied to the grid of V_{601}, the second harmonic was 50db below the level of the fundamental. Under the most favourable conditions it was found possible to make observations on frequencies as low as four cycles per second, obtained from a laboratory oscillator. A definite indication of the second and third harmonic content was observed.

Experimental work was carried out on the effect of varying sweep rate as predicted by Barber and Ursell.[5] The observed and calculated values of peak amplitude variation are compared in Fig. 8. Fig. 9 shows actual oscillograms taken with values for $a/\Delta f^2$ of 3 and 10 respectively (a = rate of change of frequency, Δf = filter bandwidth). Figs. 10 and 11 show typical analysis results, Fig. 10 giving the components of a slightly asymmetrical square wave (note the small amplitude even harmonics), and Fig. 11 the components of a short pulse. In each case the small peak at

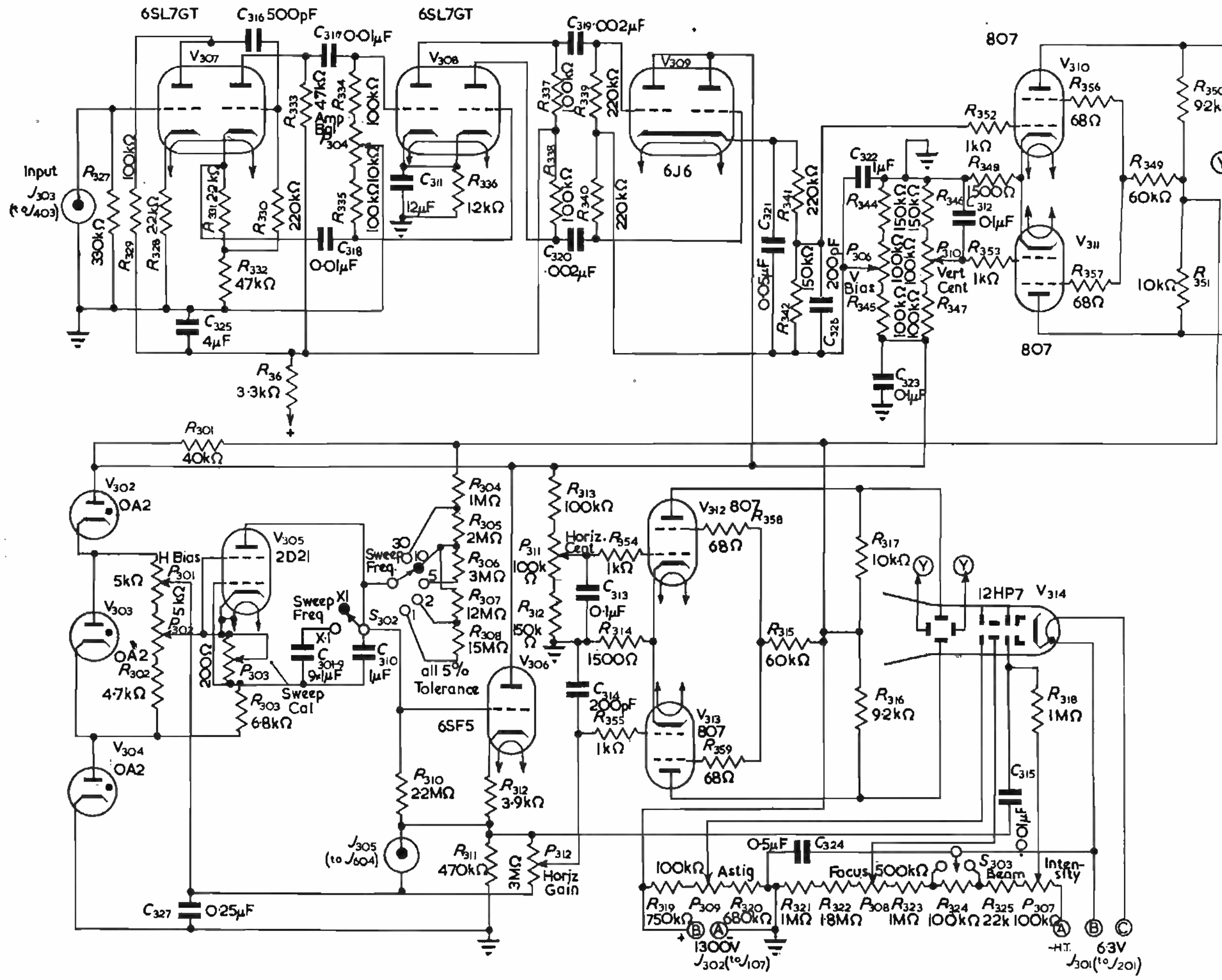


Fig. 7. Chassis No. 3—Indicator and Sweep Circuits

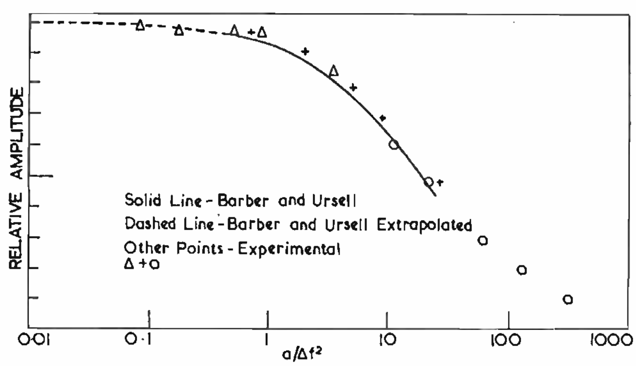
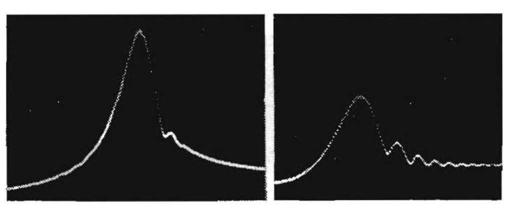


Fig. 8. Variation of Peak Amplitude with $a/\Delta f^2$

Fig. 9. Response of a Tuned Circuit to a Varying Frequency



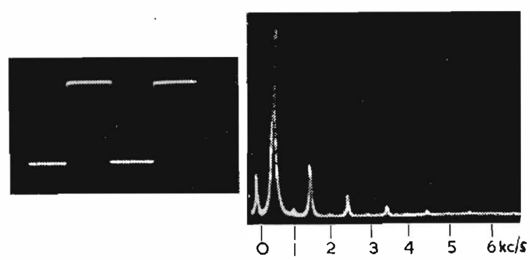
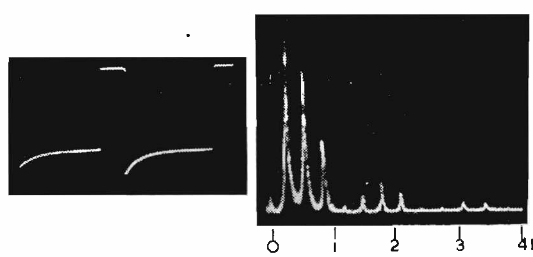


Fig. 10. Analysis of a Square Wave

Fig. 11. Analysis of a Short Rectangular Pulse



the extreme left is the zero frequency marker produced by slightly unbalancing the first modulator.

Phase Measurement

The analysis of a complex waveform cannot be considered complete by merely stating the frequency components present and their amplitudes. The relative phases are also important. A method of measuring these phase relations is indicated in Fig. 12. The unknown signal is applied to the analyser along with a reference signal of the same frequency and synchronized with the unknown. The standard signal must contain all orders of harmonics up to the highest to be measured, and the relative phases of the harmonics must be known. It is best if all the harmonics can be in phase with the fundamental, as with a short rectangular pulse.

The reference signal is applied through an attenuator and two continuously variable phase shifting circuits in cascade. One of the latter is set to zero, and the other adjusted with the attenuator until the fundamenal components of the two signals are equal in amplitude and opposite in phase, showing a zero indication on the display. The other phase shifter is then adjusted with the attenuator for zero indication of each successive component, the phase readings being observed. The attenuator does not affect the result, but its use makes it easier to set the phase shifter accurately by adjusting the output to a null point.

The success of the method is largely dependent on the

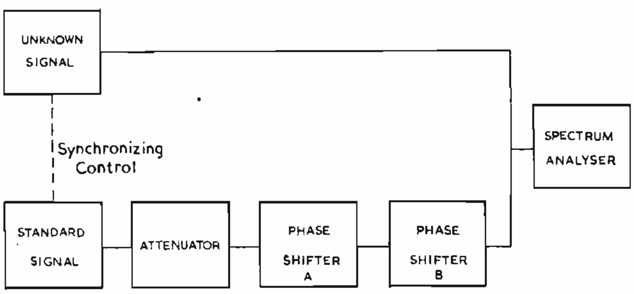


Fig. 12. Measurement of Phase

assurance with which the relative phases of the components of the standard signal are known. Non-ideal pulses may show a considerable departure from the phase relations predicted by an analysis of ideal waveforms, and care must be taken to account for this (See Appendix).

A similar method is described in considerable detail by Rogers,[15] along with some interesting experimental results. This did not come to the author's attention until after the above work had been completed.

Response Curves

The arrangement shown in the block diagram of Fig. 13 can be used to trace response curves of filters or amplifiers. The output of the mixer stage contains the difference frequencies of 0 to 20kc/s which it is desired to apply to the circuit under test. All other frequency components at this point are sufficiently high that they may be easily removed by a low-pass filter. If desired, the output of the circuit under test may go to chassis No. 4 before chassis No. 3, in order to make use of the built-in attenuators or the logarithmic amplifier.

Conclusions

The equipment described in this paper was a trial model only, and nearly every circuit could be improved in design as a result of experience with the instrument. However, the operation is satisfactory and the performance specifications on which the design was based have been met. Naturally considerable care is needed in operation, but familiarity with the controls makes this relatively un-

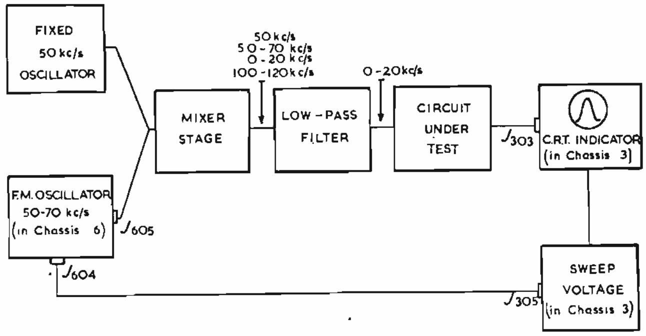


Fig. 13. Use of the Analyser to Trace Response Curves

important. The analyser is primarily a research instrument and was not intended for operation by non-technical personnel.

Acknowledgments

This article has been based on the author's Ph.D. thesis (University of Toronto, Department of Physics, 1950), and the valuable help of Prof. J. M. Anderson and Prof. R. W. McKay, who supervised the research, is acknowledged with gratitude. The author is indebted to the Research Council of Ontario for two scholarships, under which most of the research was carried out. Special thanks are due to Mr. D. W. Thomasson of Electronic Applications Research Laboratory, Exeter, for a large number of helpful criticisms and a great deal of assistance in the preparation of this paper.

Appendix

The Effects of Small Perturbations in a Short Rectangular Pulse

A mathematically perfect short rectangular pulse can be expressed in a Fourier series as:

$$y = E\left\{k + 2/\pi \sum_{n=1}^{\infty} \left(\frac{\sin n\,k\pi}{n}\right) \cos nx\right\}$$

where E, k are as defined in Fig. 14. We wish to determine the change in the relative phases of the components if the pulse shape is not perfect.

In general any recurrent waveform with period 2π can be expressed as a Fourier series:

$$f(x) = b_0/2 + b_1 \cos x + b_2 \cos 2x + \ldots + b_n \cos nx + \ldots$$
$$+ a_1 \sin x + a_2 \sin 2x + \ldots + a_n \sin nx + \ldots$$

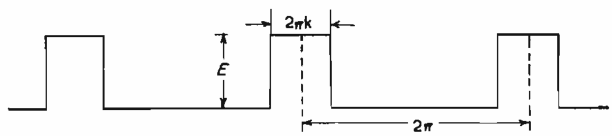
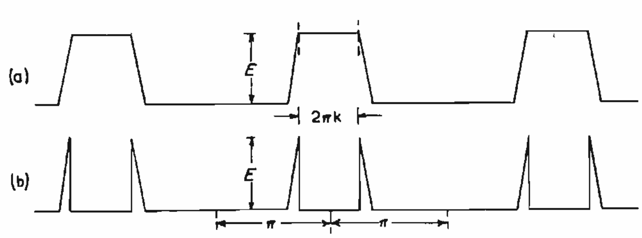


Fig. 14. Short Rectangular Pulse

Fig. 15. Trapezoidal Pulse



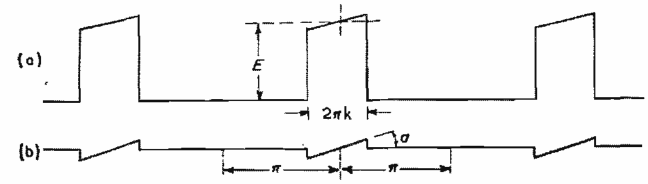


Fig. 16. Pulse with Slanting Top

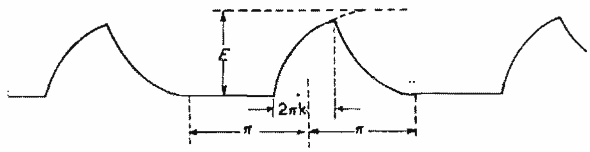


Fig. 17. Exponential Pulse

where $b_n = 1/\pi \int_{-\pi}^{\pi} f(x) \,.\, \cos nx \,.\, dx$; $a_n = 1/\pi \int_{-\pi}^{\pi} f(x) \,.\, \sin nx \,.\, dx$

or $f(x) = b_0/2 + \sum B_n \cos(nx + \delta_n)$

where $\tan \delta_n = a_n/b_n$ (phase error).

Trapezoidal pluse (Fig. 15) .... $\tan \delta_n = 0$

Pulse with slanting top (Fig. 16) ..... $\tan \delta_n = \tan a/n$

Exponential pulse (Fig. 17) .... $\tan \delta_n = n/m$

where m is the decay constant of the pulse (assumed the same for both rising and falling edges).

REFERENCES

13. F. E. Terman. Radio Engineers' Handbook, p. 505 (McGraw-Hill Book Co., 1943).
14. H. S. McGaughan and C. B. Leslie. A Resistance-Tuned, F.M. Oscillator for A.F. Applications. *Proc. I.R.E. 35*, 974 (1947).
15. W. E. Rogers. A New Method in the Analysis of Complex Electric Waves, *Rev. Sci. Instr. 19*, 332 (1948).
M. P. Givens and John S. Saby. A Simplified Analysis of the Parallel-T Null Network. *Review of Sci. Instr. 18*, 342 (1947).
H. H. Scott. A New Type of Selective Circuit and Some Applications. *Proc. I.R.E. 26*, 226 (1938).
S. W. Punnett. Audio-Frequency Selective Amplifiers. *J. Brit. I.R.E. 10*, 39 (1950).
E. Meyer. A Method for Very Rapid Analysis of Sounds. *J.A.S.A. 7* 88 (1935).

Television Filming

By V. E. Hughes*

THE association of television with film making is a new application which is proving to be one of the most successful of recent innovations in the world of television. In the film industry it is also being followed up enthusiastically for, not only does it mean a great saving in time and money during the making of films in studios, but it also allows on-the-spot events to be filmed and then projected on to a cinema screen with only a ninety second time lag, at the same time providing permanent record on film. Unlimited prints may be taken from the negative version of such a record for wider distribution.

For the past few months this system has been used at the Palais de Chaillot, in Paris, during the deliberations of the United Nations Organization, and it has enabled a completely edited film to be shown over the B.B.C. television system the same evening of the day the events took place. These films have also been shown on the New York systems the morning after.

In Paris the three-camera television unit was installed and operated by engineers of Marconi's Wireless Telegraph Co. Ltd., while Paramount Pictures Corporation provided the Theatre Television (or Kinescope) unit which takes the television pictures from a master monitor and films them.

Television v. Film Technique

To appreciate fully the great value of this merger the fundamental differences between film and television production must be considered. Of major importance in film making is the sequence when a mass of celluloid must be sorted, foot by foot, arranged into a sequence giving perfect continuity, and cut and spliced to give the finished product. Apart from the high labour cost, there is the added cost of the waste film which can easily be twenty or thirty times the amount contained in the finished picture.

Scenes are shot many times over and sometimes angles are altered and camera positions moved after scenes have been shot necessitating more film, more time, and more editing.

Television production, on the other hand, is instantaneous. The producer uses more than one camera at a time—three is the usual number—and he is presented with a picture from each at his production point. Each camera is equipped with three or four lenses (at the Palais de Chaillot, four lenses) and there is therefore a choice

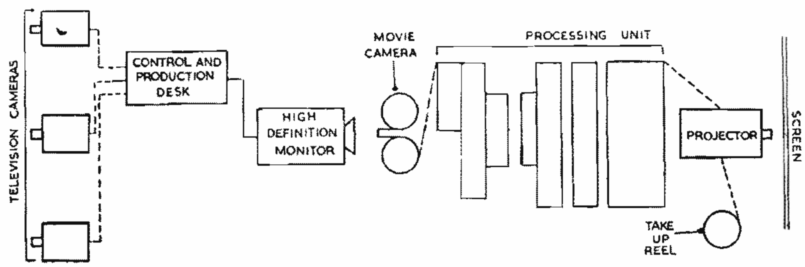


Fig. 1. The layout of the Kinescope

of twelve different "takes." The three cameras will usually be in different positions, at different angles, and at different elevations.

This combination provides the producer with a wide choice of final picture.

In practice the major "plot" for shooting is drawn up beforehand and during transmission the producer instructs two of the cameramen which angle, position (if they are on dollies) and lens to use next, while accepting a picture from the third. The facility and rapidity with which twelve lenses, three cameras, three positions and three angles can be varied and used makes for smooth and fluid continuity.

Combined Film and T.V. Technique

The new technique, then, is the fusion of television production with the permanency of films, the slightly inferior definition of the television picture being offset by the enormous saving in time, labour, and cost.

In Paris the complete organization started with three

* *Marconi's Wireless Telegraph Co., Ltd.*

television cameras strategically placed in the Chamber in use and their respective cables led to the television control room. In this control room the camera control operators, engineers, and producer took the three transmissions. Following normal television practice the producer used his cameras to give a completely edited programme, the master picture of which was reproduced on an eight inch cathode-ray tube. A few inches from this tube was the film camera and its associated sound head, sound being brought through from microphones in the Chamber in the normal television manner.

The camera records both vision and sound on 35mm film (16mm can be used) and the Kinescope process starts. From the camera the film passes through a series of tanks which completely process it. At the end of the process, which includes drying, the film goes through a projector for monitoring purposes, and is then wound on to its final reel (see Fig. 1).

Only ninety seconds elapse from the time a frame passes before the cathode-ray tube until it is wound on the reel.

The equipment is made up of three basic units. First there is the high definition television monitor capable of displaying a positive or negative picture on the cathode-ray tube. This change is achieved by simple reversal of polarity. The unit includes an electronic shutter as an integral part to allow the 30 frame (in Britain it would be 25 frame) television signal to synchronize, or resolve, to the motion picture rate of 24 frames per second.

This monitor can, of course, be adjusted to receive any television standard of line and frequency. The circuits are designed for a bandwidth of 10 megacycles but can easily be adapted to take higher definition standards. The function of the electronic shutter is to blank out the cathode-ray tube at appropriate intervals in order to synchronize with the pull-down of the shutterless movie camera; it is completely automatic and assures one complete television frame being exposed on one film frame. The polarity of the picture (positive or negative) is controlled by one switch while simple controls adjust for non-linearity of incoming signals, for brightness and contrast.

The second unit is the shutterless cameras and its associated film magazine which contains 12,000 feet of film. It also incorporates a newly designed sound-on-film recorder which has no moving parts. The 12,000 feet of film will give continuous recording for over two hours. The sound track is a variable density type and sound fidelity is limited only by the reproduction system in a theatre. This unit photographs the image on the cathode ray tube of unit 1, and records the sound passed through the microphones. This produces a completely exposed single-system film.

The third unit is a high-speed processing machine designed to develop, rinse, fix, wash, and dry the exposed film. It is processed at a synchronous sound projector speed of 90 feet per minute, 24 frames per second, using high temperature, high pressure spray techniques. Fast drying is accomplished by means of squeegees and hot air and the film quality, using these techniques, is equal to or better than standard release quality. At the end of the processing chain the film can, if required, be passed through a projector for theatre use or monitoring before being wound on its finished reel. The complete process is automatic—one control starts the camera, process machine, theatre or monitor projector, and final wind. All temperatures are thermostatically controlled and all components are interlocked to ensure simultaneous stopping and starting.

The film normally used is standard 35mm fine grain and packaged chemicals allow unskilled operators to take charge.

Physically the whole unit takes up 60 square feet of floor space and can be situated (in a theatre) anywhere near to the projectors.

Hot and cold water supplies are needed and a drain for the disposal of surplus water and solutions.

Since this article has been written the major British film companies have been experimenting with television as an aid to production in the studios and on sound sets, and it seems probable that there will be considerable development in this field in the near future.

BALANCING AERIAL COUPLING CIRCUITS *

A FORM of receiving aerial arrangement that is often used for ultra short waves is one employing a dipole aerial connected to a parallel pair feeder and forming a symmetrical circuit. The first tuned circuit of the receiver, however, is often arranged with one side grounded, and the asymmetry that is thereby introduced tends to result in setting up currents in the tuned circuit which do not arise from excitation of the aerial but derive from co-phasal pick-up by the conductors of the parallel pair feeder. In consequence there tends to be set up in the tuned circuit interference such as that originating from motor vehicles, and the directional diagram of the aerial becomes modified in a manner which it is not easily predictable.

One method of reducing these effects that is well known is to insert between the tuned circuit and the coupling coil at the end of the feeder an electrostatic screen which is earthed. The aerial circuit is then coupled with the tuned circuit only in relation to balanced currents and the asymmetrical capacitance coupling that transmits co-phasal currents is avoided. Working, however, with ultra short waves, this method leads to a diminished inductive coupling and for this reason cannot always be applied.

* *Communication from the Telefunken Company via E.M.I. Ltd.*

A simple method, however, that is not susceptible to this objection is to off-set the earthing centre tap on the coupling coil, and such an off-set tapping is shown in Fig. 1. With the earthing tap displaced from the centre point in the correct sense and to the correct degree the excitation of the tuned circuit by co-phasal currents in the feeder can be entirely eliminated. The sense of the displacement of the tapping point is as shown in the direction of the ungrounded end of the inductance of the tuned circuit. This has the effect of reducing the capacitance coupling to the low potential end, so achieving a balance. The coupling coil will naturally be wound over the inductance of the tuned circuit.

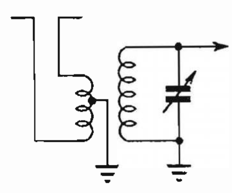


Fig. 1. The off-set centre-tap

It is known that the co-phasal effect tends also to be set up in frame aerial circuits. The effect is then known as "Antenna" effect and can cause large errors when a frame aerial is used for the purpose of determining bearings. To reduce such errors the method of off-setting the tapping point of the coupling coil may again be usefully applied and the method is clearly of wide application. Strictly speaking, the compensation holds good for a single frequency only, but in practice the compensation is sufficiently precise for satisfactory operation over a useful range of frequencies.

A Very High Impedance Valve Voltmeter

By D. E. Brown* and K. Kandiah*

This instrument has ranges of 10, 20, 50, 100, 200 *and* 500 *volts full scale, positive or negative with respect to earth. Accuracy on all ranges is* ± 2 *per cent of full scale reading. The leakage resistance of the input terminal to earth is greater than* 10^{14} *ohms and the instrument feeds a positive ion current of less than* 10^{-10}*A into the circuit under test.*

THE increasing use of low current devices in electronic circuits has created the need for a voltmeter with very high input resistance. The conventional type of valve voltmeter has one low basic range and higher ranges are provided by the use of an input voltage divider. The impedance of this divider is limited to values between 10 and 100 megohms owing to the poor long term stability of very high value composition resistors. An electrostatic voltmeter cannot be considered a satisfactory solution since the scale is non-linear, and the instrument is rather fragile for voltages less than 500.

A valve voltmeter which has a very high impedance has been described by Dr. F. T. Farmer[1]. The circuit as published is designed for battery operation and no provision is made for measuring voltages negative with respect to earth. The authors' design was originally inspired by Dr. Farmer's instrument but voltages of either polarity may be measured and the voltmeter is entirely mains operated.

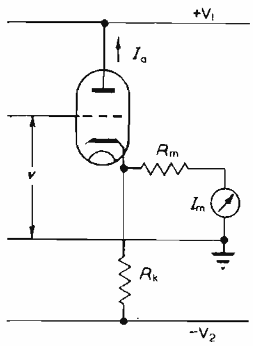


Fig. 1. Circuit diagram of simple cathode-follower valve voltmeter

Circuit Details

The circuit used is basically a cathode-follower. A simple use of this circuit as a voltmeter is shown in Fig. 1. If this is to be used to measure voltage ± v then the following conditions must be satisfied.

$$V_1 > v$$

$$V_2 > \frac{R_m + R_k}{R_m} \cdot v$$

Also the maximum anode current in the valve, which occurs when voltage + v is applied to the input, has a value given by:

$$I_a = I_m + \frac{V_2 + v}{R_K}$$

The maximum anode-cathode voltage in the valve will appear when voltage $-v$ is applied and is given by:

$$V_{A-K} = v + V_1$$

If a design of this circuit is attempted for the case where v is 500 volts it will be found that either V_2 or I_a become very large. The grid current in the valve will also have a very high value owing to the large anode-cathode potential. To overcome these difficulties two extra valves are used, one to maintain constant voltage across the input valve, the other to supply constant current from the negative high tension supply. A complete circuit diagram is given in Fig. 2. The input terminal is connected directly to the control grid of V_2. The voltage across V_2 is held constant by V_1 acting as a cathode-follower with V_2 as the cathode load. The screen of V_1 is held 40 volts positive above its grid and the grid is held 40 volts above the cathode of V_2. The anode supply of V_1 is 700 volts.

The cathode load of V_2 consists of switched resistors R_8-R_{14} and valve V_3 is a pentode passing constant current due to the feedback introduced by R_1 in its cathode. The screen supply is 40 volts and the grid is held 90 volts above the negative supply rail of 700 volts. The voltage changes on the cathode of V_2 are indicated on the meter M_1 .which is connected to it through resistors R_8-R_{14} The "earthy" end of M_1 is taken to the slider of VR_1, the set zero control. Since with zero voltage applied to the input the cathode of V_2 will be a few volts positive a drop of 10 volts is provided across VR_1 to bring the meter reading to zero.

Power Supplies

All the necessary supply voltages are provided by the mains transformer T_1. Metal rectifiers are employed throughout since the current consumption is low and their use greatly simplifies construction. Heater windings (a) and (b) and the two 100 volt windings should be insulated for 1kV working. The insulation of heater winding (a) and the 100 volt winding used to supply V_1 should be greater than 1,000 megohms. Both windings should share a separate electrostatic screen.

Components and Valves

The only critical components in the unit are the resistors R_8-R_{14} and the meter M_1, since the accuracy of these directly affect the accuracy of the instrument. M_1 is 100 microamp full scale deflexion, first grade meter, with an accuracy of ±1·5 per cent. The resistors should, if possible, be wire wound with an accuracy of ±0·1 per cent. In order to use a standard value of resistor R_8 has been made 100kΩ and a lower total value is obtained by shunting with R_7, which can be a carbon grade 1 resistor. The lower value is needed to compensate for the output impedance of V_2 and the resistance of the meter. Together these add up to a total resistance of 5kΩ. Where very high accuracy is required on the low voltage ranges R_7 should be selected to match V_2.

The input valve V_2 is a CV432 (Mullard ME1400) run under low anode and heater voltage conditions to reduce grid current. V_1 and V_3 are CV1129 (selected Cossor MS Pen T) which have an anode voltage rating of 3kV. It should be noted that when reading ±500 volts V_1 or V_3 has to withstand an anode voltage of 1·2kV. This is the only limiting factor to the maximum voltage which can be measured with this type of voltmeter. The upper safe limit is 1,000 volts with the valves chosen. If this extra range is required the positive and negative rails should be increased to 1,300 volts. This higher range has not been provided since accurate electrostatic voltmeters are available for this range.

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

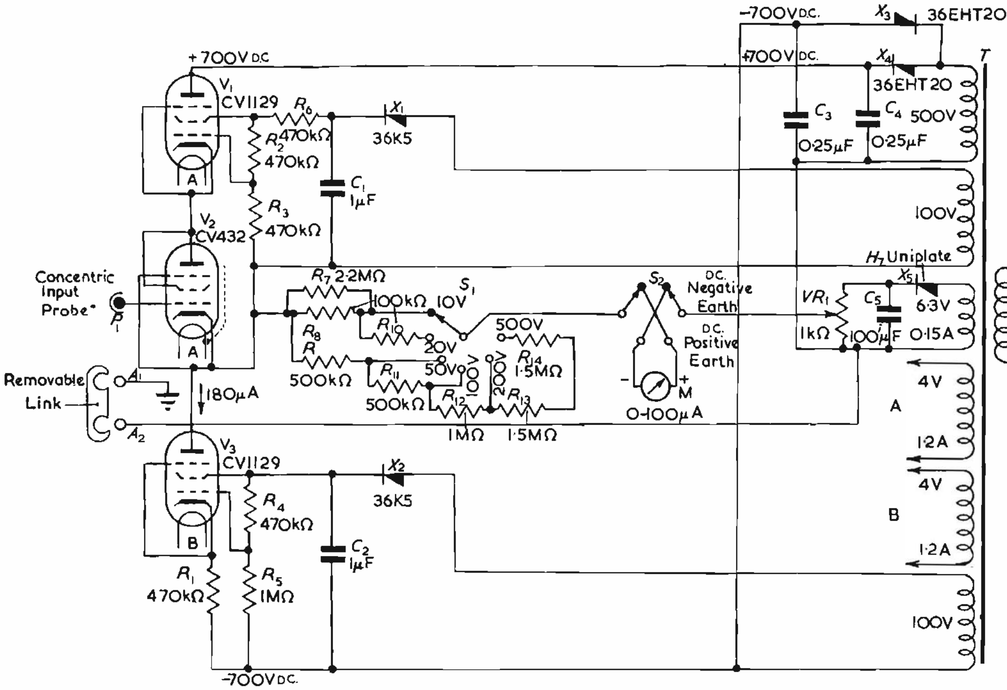


Fig. 2. The complete circuit diagram

The high impedance terminal is a polythene moulded concentric socket and a convenient length of polythene insulated cable with a plug is provided. The free end of the cable has the braiding stripped for a few inches and crocodile clip terminations are fitted. Care must be taken to keep the insulation clean and free from dust on the input side. The low impedance or "earthy" side of the input is taken to a bakelite terminal A_2 which is normally connected to an earth terminal by means of a removable link. With the link removed the "earthy" terminal A_2 can be connected to a low impedance point in the circuit under test, for example, a cathode, and the grid-cathode potential of a valve can be measured directly.

Accuracy and Zero Drift

The accuracy of the instrument is ±2 per cent or better on all ranges. On ranges 100 volts and above the accuracy is chiefly determined by the meter and series resistors. There is no noticeable zero drift over several hours from five minutes after switching on. A ±10 per cent change in mains voltage produces an error of ±0·2 volts on all ranges.

Conclusion

The instrument described has an input impedance higher than that of any type of valve voltmeter known to the authors. The accuracy is adequate for most electronic circuit measurements. Two instruments of this type have been in use at the A.E.R.E. Harwell for the last three years and have proved to be very useful.

Acknowledgments

The authors are indebted to the following members of A.E.R.E., Harwell, Mr. Lomas for constructing the instrument, Mr. H. G. May for checking the accuracy and stability of the unit, Mr. T. P. Lynott for designing the mains transformer, and to the Director for permission to publish this article.

REFERENCES

1. FARMER, F. T. An electrometer for the measurement of voltages on small ionisation chambers. *Proc. Phys. Soc. LIV*, 435 (1942).

TELEVISION IN COMMERCE

A demonstration yesterday of a private television link between the Whitehall branch of Glynn Mills and Company and its pay department and ledger division at Osterley Park represents possibly the first practical application of this medium to the purely commercial field.

Although the radio vision link is still only experimental—its economics and the granting of a Post Office licence are matters under discussion—it promises to be a useful aid for the distant examination of confidential documents and other material. On this occasion it was concerned with the affairs of banking.

In the London office a special viewing set had been installed which could present a life-size, or larger, picture. About 10 miles away, at the Osterley Park branch of the bank, was a television camera focused on the page of a ledger, or perhaps a cheque, which had to be placed in position by hand. By remote control, using a Post Office line which also carried any conversation between the two offices, the camera could be moved over the face of the document and a close examination (greater than life-size) made of any part of it. The quality of reproduction was very good, even the numbers on a page of a telephone directory—a test piece—being clearly discernible.

The equipment has been developed by Pye Limited, and the television camera used for the demonstration was a new and exceptionally small one, it being little larger than the usual 16mm cine-camera. The radio link operated on a wave-length of about 15cm, and the British 405-line standard for picture definition was used. Transmission power was stated to be about half a watt of electrical energy which was directed from Osterley on a three-degree beam.

—*The Times, April* 23, 1952.

Electronics in Naval Research

A RECENT article in this journal (October, 1951) dealt with some of the opportunities open to electronic engineers in research and development establishments of the Ministry of Supply, and laid stress on the wide variety of work undertaken in the various laboratories concerned. The purpose of the present account is to give similar details of the Admiralty organization which, although not as large as that of the M. of S., nonetheless includes laboratories engaged in very important work, much of which is carried out on behalf of the Army and the Royal Air Force no less than of the Navy.

Naval science, of course, embraces a great many fields not directly concerned with electronics. For example, researches into the chemistry of new materials for construction or propulsion, or into the efficiencies of new types of fuel burners, boilers and turbines, are not fundamentally electronic in nature, though in practically every one there is some use of electronic instrumentation and recording gear.

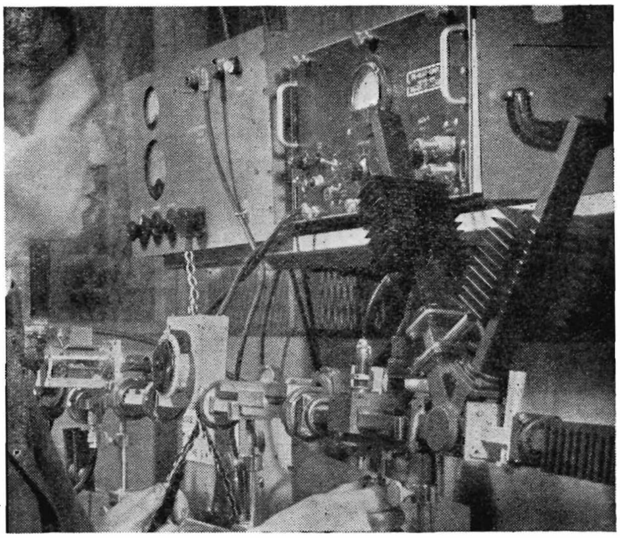
There are, however, several other fields, notably those of radio communication, radar, underwater detection, presentation of "battle information" and weapon control, in which electronics play a major part. Even more important than any single one of these are the original researches on new techniques and new types of components, especially valves, without which little real progress would be possible.

Before outlining briefly some of the current work in these various fields, it may perhaps be helpful to mention the general structure of the research and development organization of which they are part.

The "scientific arm" of the Navy dates from the end of the first World War, when the Admiralty's *Department of Scientific Research* was formed with the general instruction to organize and direct research for Naval purposes. Incidentally, the D.S.R. anticipated by several years any similar organization in the other Services. Throughout the inter-war years its importance and influence in Naval affairs gradually increased, until the 1939-45 war brought about a sudden and very large expansion in both its responsibilities and its size. During the war, plans which had been tentatively proposed in 1938 for a more integrated scientific service were temporarily shelved, but in 1945 the long-standing title *Director of Scientific Research* was changed to that of *Chief of the Royal Naval Scientific Service*, and the R.N.S.S. itself was born.

Under present arrangements, nearly all civilian scientists* in Admiralty employment belong to the R.N.S.S., in which there are the same ranks and grades of scientific and experimental officers as were described in the Ministry of Supply article already mentioned. Although all come under the general administration and supervision of the Chief of the Service, the actual laboratories where they work fall into two classes, namely (a) those working under the direction of various specialist Admiralty departments, such as Radio Equipment, Electrical Engineering, or Underwater Weapons, and (b) those working directly under research departments headed by members of the R.N.S.S. Broadly speaking, the former laboratories have responsibility for research, development and production within the limits of their own specialist fields, whereas the latter investigate problems common to several of the specialist departments, besides paying attention to fundamental and long-term research having no immediate practical applications. Table I illustrates this arrangement.

* *Exceptions are those employed in a number of other technical departments of long standing. They comprise mainly structural, mechanical and electrical engineers engaged in heavy construction and maintenance work in dockyards and elsewhere.*



A microwave research bench at the Services Electronics Research Laboratory.

It would obviously take a great deal of space to describe the applications of electronics in more than a few of these laboratories, and it is therefore proposed to limit what follows to three, namely the *Admiralty Signal and Radar Establishment* (communications and radar equipment), *H.M. Underwater Detection Establishment* ("Asdic", hydrophones, etc.), and the *Services Electronics Research Laboratory* (basic valve research and new techniques such as frequency-modulated radar, infra-red detectors, etc.).

Table 1

ADMIRALTY SPECIALIST DEPARTMENTS	LABORATORIES AT :
(1) Compass Department ..	Admiralty Compass Observatory.
(2) Dockyards Department ..	Admiralty Chemical Department. Central Metallurgical Laboratory.
(3) Electrical Engineering ..	Admiralty Engineering Laboratory.
(4) Naval Construction	Admiralty Experiment Works. Naval Construction Research Establishment.
(5) Naval Ordnance	Admiralty Gunnery Establishment.
(6) Naval Ordnance Inspectorate	Naval Ordnance Inspection Laboratories.
(7) Radio Equipment	Admiralty Signal and Radar Establishment.
(8) Underwater Weapons ..	Underwater Countermeasures and Weapons Establishment. Underwater Detection Establishment. Torpedo Experimental Establishment.
(9) Engineer-in-Chief	Admiralty Engineering Laboratory. Admiralty Fuel Experimental Station.
R.N.S.S. DEPARTMENTS	**LABORATORIES AT :**
(10) Aeronautical and Engineering Research	Admiralty Materials Laboratory.
(11) Operational Research ..	—
(12) Physical Research	Admiralty Hydro-Ballistics Research Establishment. Admiralty Research Laboratory. Services Electronics Research Laboratory. Royal Naval Physiological Laboratory.
(13) Research Programmes and Planning	—

Admiralty Signal and Radar Establishment

The A.S.R.E., which was established during the last war with a nucleus of scientists from the older H.M. Signal School, is now one of the largest Admiralty experimental establishments. It is at present in process of moving to new modern laboratories where there are being installed first-class facilities for all types of transmitter and receiver development, aerial research, and radio propagation investigation at all wavelengths. Among the projects currently in hand are (a) equipment for rapid presentation and evaluation of data from the many radar sets now required for such operations as long-range warning of attack, target location and ranging, close fire-control, and special weapon control, (b) improved radar sets to perform these functions, (c) V.H.F. communication equipment for fighter-direction from aircraft carriers, (d) special types of automatic telegraphy gear for both long- and short-range communications, and (e) improved radio aids to navigation.

Other problems being tackled include those of better radar for submarines, the avoidance of mutual interference between the large amount of radio gear now essential in a warship, aerial systems stabilized against ships' movements in a rough sea, and the increasingly important matter of greater reliability of complex equipment in action and in extreme conditions of climate.

There is virtually no branch of radio and electronic science which does not find a place in the A.S.R.E., whose history of accomplishment stretches as far back as 1905 when the Navy's first civilian wireless expert, Mr. H. A. Madge, was appointed to continue the early work of Admiral of the Fleet Sir Henry Jackson, the "father of naval wireless."

H.M. Underwater Detection Establishment

H.M.U.D.E. has always been mainly associated with the development of equipment for the underwater detection of submarines. The well-known "Asdic" device was produced in its laboratories, and improved apparatus of this type remains one of its most important commitments. Here, therefore, the accent is on very low frequency electronics, as opposed to the very high frequencies at the A.S.R.E., and such equipments as piezo-electric transducers and magnetic amplifiers feature in its everyday work.

With the growing speeds and endurances of submarines, as well as the greater lethality of their weapons and their ability to remain submerged almost indefinitely by the use of "snort" breathing devices, the work of H.M.U.D.E. remains as important as ever. Not only does it include the development of apparatus as mentioned, but also much original work on the acoustic properties of the sea, and all craft that operate on or in it.

Services Electronics Research Laboratory

The S.E.R.L. is one of the Laboratories working under the direct control of an R.N.S.S. research department, the *Department of Physical Research*. It is also an inter-Service laboratory, having been established in 1946 to meet the needs of all three Services for the development of specialized valves and other equipment often requiring characteristics superior to anything previously achieved.

The laboratory is thus largely concerned with fundamental research, and indeed is not unlike the research department of a university. Since its inception it has been responsible for many new types of magnetrons for very short wavelengths, for various developments of the klystron valve as a receiver local-oscillator in the same bands, and for the development of "sub-miniature" valves for a wide variety of applications.

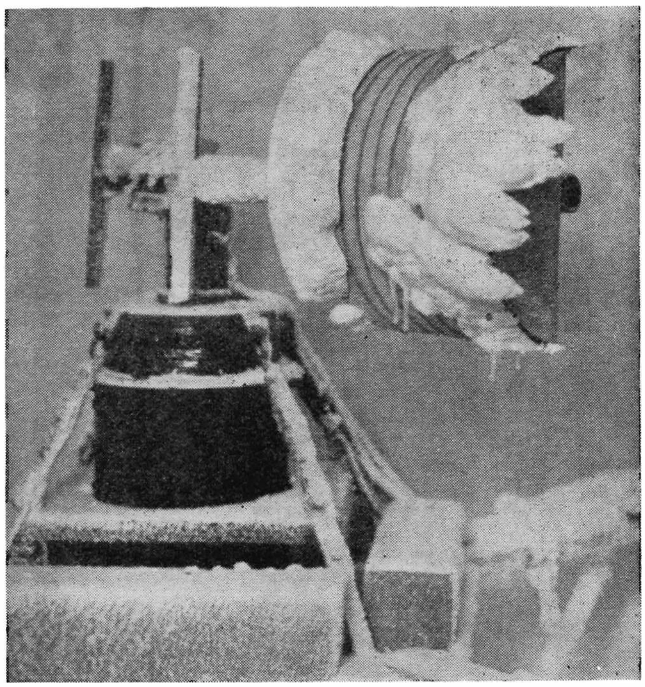
Special types of cathode-ray tubes for plotting and "storing" information from radar displays have been evolved, and some of the most significant research on the fundamental behaviour of travelling-wave tubes has been done in the laboratory. Only a year ago, the S.E.R.L. assumed also inter-Service responsibility for research and development on infra-red devices for various "see-in-the-dark" detection and signalling techniques.

Besides its work in developing valves and equipment, the laboratory has also carried out, in conjunction with certain university and commercial research teams, an extensive investigation into propagation conditions in the millimetre radio waveband and the infra-red spectrum. This work is still continuing, as are also investigations of such matters as the fundamental advantages of frequency-modulated continuous-wave radar over pulsed systems, or the exact nature of electron motion in various types of magnetron.

The laboratory has also set up a small factory where some of the more urgently needed special valves can rapidly go into limited production immediately their development is complete.

Conclusion

The foregoing does not pretend to be a comprehensive account of the work of even the three laboratories discussed. It is hoped, however, that it will have given an idea of the scope for electronic engineers in these laboratories. In conclusion, it may be mentioned that there are arrangements whereby workers at one laboratory may transfer temporarily to another if by so doing they will be better able to pursue their particular problem of research or development. The R.N.S.S. also offers opportunities for attendance at university vacation schools, meetings of learned societies and international scientific conventions. Publication of the results of research not subject to security restrictions is encouraged, and the Service has its own publications in which work of a confidential nature may be discussed. Quite a number of higher degrees have been awarded to R.N.S.S. members for theses based on their official work.



Testing an aerial under extreme climatic conditions at the Admiralty Signal and Radar Establishment.

Metal Film Resistors

By R. J. Heritage*

IN the electronic field of today there is an ever growing need for new components or alternatives to the existing types, and since most types of components find only limited application, any new development is worthy of note. At present, resistors are available in three forms (a) the solid carbon type, in which carbon is bonded with a suitable resin in the form of a cylindrical rod (b) the carbon film type, composed of a thin carbon film cracked at high temperatures on a ceramic body, and (c) the wire-wound type, in which a length of a high resistivity alloy is wound on an insulating former. An alternative resistive element is the thin metallic or metallic alloy film deposited by a suitable means on an insulating base.

To be of any practical value, a resistor must possess the following properties:

(a) stability, under normal working and varied climatic conditions.

(b) repeatability without undue expense, by a method adaptable to mass production,

(c) robustness,

(d) low temperature coefficient of resistance and low noise level,

(e) high working voltage with a small size to wattage ratio.

Properties of Thin Metal Films

It has been found that the conductivity of a thin metal film depends to a great extent upon its thickness, conductivity occurring only after a certain critical thickness has been reached. For silver this critical thickness is about 45 Angstrom units ($1A = 10^{-8}$cm), and the film thickness at which any constancy of conductivity is obtained is about 400A, even greater thicknesses of film giving conductivities lower than for the massive metal.

Reinders and Hamburger have shown that the curve of resistivity of a silver film plotted against its thickness rises sharply at about 350A and shows that the resistivity of the bulk metal is not attained until about 3,000A is reached. This thickness of 350 to 400A is believed to be the mean free path of the electron in silver. For thicknesses greater than 350 to 400A the resistivity appears to vary only slightly until the normal bulk metal value is reached, whereas lesser thicknesses give resistivities which vary from 10^3 to 10^7 times those of the bulk metal.

From these considerations it will be seen that if metal films are used to give satisfactory resistor elements then the film thickness should exceed the mean free path of the electron in the metal. If films of less than this thickness are used, difficulties will be experienced in obtaining repeatable values of resistance, since differences of a few Angstrom units will be accompanied by relatively large differences in resistivity.

Methods of Producing Thin Metal Films

The methods available for producing thin metallic films on non-conducting base materials are as follows:—

1. *Chemical reduction from aqueous solutions.* A number of aqueous solutions have been devised by means of which metal films may be deposited on glass, ceramics and plastic materials. The mirroring solutions of Brashear and Hilger, for instance, are well known for obtaining highly reflecting silver films on glass.

These solutions may be modified to deposit fairly adherent films of silver on other base materials. Other solutions available can be used to provide films of copper, gold, platinum, antimony, and alloy films of certain of these metals. The mechanical weakness of the films obtained by this method, and the difficulties entailed in controlling the deposition period, negative the usefulness of the films for resistor making, particularly from a mass production aspect.

2. *Evaporation.* In this process, the material to be coated is placed at a distance from a heating element to which is attached a sufficient quantity of the metal to be evaporated, and the whole is fixed in place inside an evacuated jar.

The metal is evaporated by heat from the element and molecular particles are deposited on the cool surface of the material. The rate of deposition of metal can be varied by regulating the temperature of the heater and the thickness can be controlled by varying the period of deposition. Resulting films are adherent, especially on glass surfaces, and the method is adaptable for use with most metals. Moreover, the resistance value can be continuously recorded if necessary making this method useful for producing resistor elements, although it is doubtful how adaptable the method is to mass production.

3. *Cathode sputtering.* After being carefully cleaned the material to be coated is placed on an iron anode, mounted in a suitable jar. The cathode, which consists of the metal to be sputtered, is placed near the anode. After evacuating the jar, a potential of between 1,000 and 15,000 volts is set up between the electrodes and a slow deposition of metal takes place on the material on the anode. The balance between gas pressure and potential is critical and needs constant maintenance. The process is, however, available for the deposition of a number of metals and yields firmly adhering films on many base materials.

The disadvantages of the process are the slow rate of deposition and the high voltage used, making it inferior to the evaporation method for resistor making.

4. *Firing-on method.* This method is an adaptation of the process used in china decoration and is suitable for the deposition of the noble metals whose compounds are readily reduced by heat. Examples of these metals are silver, gold and those of the platinum group such as platinum, palladium and rhodium. The metal compound is dissolved in a suitable oil, such as oil of lavender or oil of rosemary, and this solution is applied to a glass or other high temperature base material and the base heated. The oil is burnt off and the compound reduced to the metal, resulting in a fine metallic deposit. For good adherence the base is then heated to its softening point, when the metal film bonds firmly on the surface.

The method lends itself readily to a production process for resistors, since the solution may be applied by painting, dipping, spraying or spinning. Control of resistance is dependent upon the choice of metal and the concentration of the original solution.

From the foregoing, the two most suitable processes for mass production appear to be the evaporation and the firing-on methods, and of the two the firing-on process is the simpler.

Choice of Metal

The choice of resistor metal is wide but since emphasis will be laid on the stability of the resulting resistance the

* *T.R.E., Malvern.*

more obvious selections will be made from the noble metals. These metals are unaffected by atmospheric influences and would thereby provide the required stability. In addition they may be deposited in thin films by the firing-on process on high-temperature base materials. This would enable the final resistors to have high working temperatures and large wattage dissipations are possible.

Furthermore, alloys of the noble metals can be deposited by the reduction of mixtures of the metal compounds by heat, and since alloys possess higher resistivities and lower temperature coefficients of resistance than the metals themselves, the alloy films will be preferable for making the higher resistance values.

Limitations of Films

Using metal films as deposited by one of the above methods, the range of resistance values will be restricted by the permissible size of the resistor. The resistance R of a metal film of resistivity ρ and thickness t is given by

$$R = \frac{\rho . L}{t . w}$$

where L is the length and w is the width of the resistive path. If the film is considered to be made up of a number

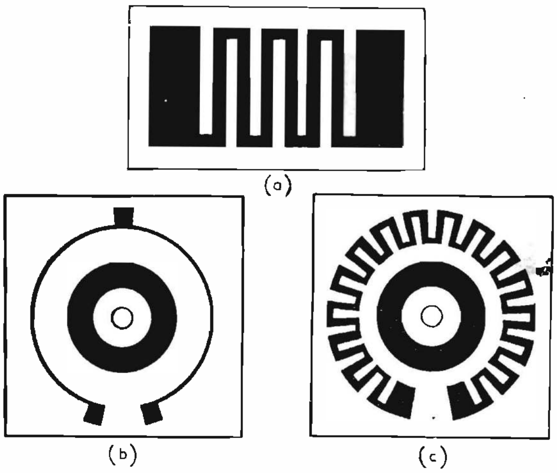


Fig. 1. Some forms of fixed and variable resistors for flat plate construction

of squares then the resistance of each square is independent of its size and the resistance value will be found from

$$R = \rho / t$$

the resistance of a unit square thus depends only upon the resistivity ρ, and the thickness t.

Assuming a film thickness of 500A and a resistivity of 100×10^{-6} ohm/cm (the resistivity of nichrome), the maximum resistance for a unit square will be 20 ohms. On a rod of 0·125 inch diameter and 1 inch long this would give a resistance of about 50 ohms.

For repeatable resistance values it has been shown that the thickness, t, should exceed the mean free path of the electron in the metal. It is evident therefore that for a wide range of resistor values it is not sufficient to vary only resistivity and thickness but the factor L/w must also be varied.

Meandering Technique

It is found that if a solution of a noble metal compound in a suitable oil is applied to a glass or glazed ceramic base and then heated to about 400°C, the compound is reduced to the metal but the resulting film does not adhere strongly to the base. In this loosely bonded state the film is easily scratched through with a sharp metal point and this property offers a useful method whereby high values of resistance may be made from comparatively low resistance areas.

To provide resistors with a wide range of values on flat plates, the "meandering technique" has been applied successfully. A glass or a glazed ceramic plate is coated with a uniform metal film and fired at 400°C; the metal is scribed according to the pattern shown in Fig. 1(a), the shaded areas representing the final metallic pattern, the clear portions being the lines removed by the scribing operation. After "meandering", the base is again fired, this time at its softening temperature at which the metal film bonds firmly into the semi-plastic surface.

By scribing a unit square of a given film to the pattern of Fig. 1(a) in 10 equally spaced lines, the effective length will become 10 times greater and the effective width 10 times less, giving an increase of 100 times in its resistance. In short, from a given square of metal film whose resistivity

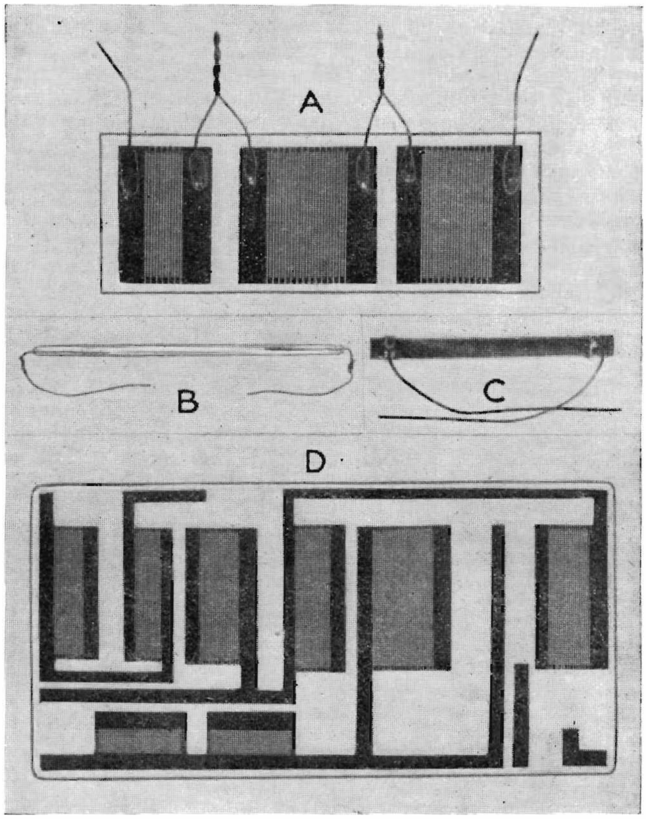


Fig. 2.

(a) Three fixed resistors made by the meandering technique on a glass plate 3 inches × 1 inch (values 6,000; 12,000; 7,000 ohms).
(b) Metallized fibre sealed in a glass tube with platinum and contacts, value 6,000 ohms.
(c) Spiralled pattern on a glass rod, value 10,000 ohms.
(d) Complete circuit of wiring and resistors before soldering of other components.

and thickness are known, the final resistance value can be predicted with considerable accuracy if the dimensions of the lines made in the scribing operation are known. This double-firing process, with a scribing operation between the two firings is also applicable to metal films deposited on suitable rods; helical lines can be scribed by means of a machine, the final resistance being variable according to the pitch of the helix.

Experimental Resistors

Using the double-firing process outlined above, a number of experimental resistors was made. The metal film used in all the samples was a gold-platinum alloy with the approximate composition 60 per cent gold, 40 per cent platinum. This film when 1,000 Angstrom units thick, had a specific resistance of 75×10^{-6} ohm/cm and a temperature coefficient of resistance of $6{\cdot}5 \times 10^{-4}$ per degree centigrade.

Fixed Resistors On Flat Glass Plates

In order to find the stability and general characteristics of the metal film resistors, a number of samples was made and exhaustive tests were performed. The samples were made on 1 inch × 1 inch glass sheets 0.05 inch thick, the glass having a softening temperature of about 700°C. For test purposes terminal wires were soldered directly on the films using ordinary soft-soldering technique, care being taken to avoid local overheating of the glass. Fig. 2(a) shows a typical glass plate (3 inch × 1 inch) with three resistors, each scribed with 20 lines per inch; (the values are about 10,000 ohms each).

Test results showed these resistors to be stable, without protection, representative samples varying by less than 1 per cent after climatic cycling. Measurements indicated that on resistors of from 5,000 to 50,000 ohms (1 inch × 1 inch plates) the noise was about 0.03 microvolt per volt when the samples were dissipating 2 watts. Wattage breakdown tests on 50,000 ohm specimens (on 1 inch × 1 inch plates) showed that 8 to 10 watts were required before breakdown, failures usually occurring by fracturing of the glass plates.

From the tests performed it was concluded that the metal film resistor is extremely stable and reliable, and possesses most of the properties characteristic of a satisfactory resistance element.

The flat form of resistor lends itself readily to flat-plate circuit construction of the "printed wiring" type where resistors and connecting wires may be conveniently arranged in a two dimensional pattern. An example of this type of construction is shown in Fig. 2(d) which comprises a circuit with conductors and resistors to which other components may be soldered.

Fixed Resistors On Glass Rods

To conform with the more conventional type of resistor, a number of resistors was made by "spiralling" on glass rods. In this form the thin film resistors are more suitable for replacement of the existing types. An example of this form is shown in Fig. 2(c). A typical specimen with a helix of 56 turns per inch on a 0.2 inch rod gives a resistance of about 10,000 ohms per inch length (using a gold-platinum film of 1,000A).

Metallized Filaments

Glass or quartz fibres of 0·001 inch diameter when metallized with the gold-platinum alloy used above to a thickness of 1,000 Angstrom units give resistances of about 2,000 ohms on 1 inch lengths. From this it is evident that if considerable lengths of fibre could be metallized and then wound on suitable formers, they would provide high resistances in comparatively small spaces, and might ultimately rank as miniature components comparable with the existing wire-wound resistors.

It was found that both glass and quartz fibres could be metallized by the firing-on process and a range of resistances from 2,000 ohms to 10,000 ohms per inch was made on 0.001 inch fibre by varying the film thickness.

One inch pieces of the metallized filaments were soldered between tags set on a plastic sheet and samples were tested in the unprotected state. On climatic cycling, the change in resistance was found to be less than 2 per cent, noise measurements at 0·5 watt gave values of about 0·06 microvolt per volt, while wattage loading tests showed breakdown at about 0.8 watt for the glass filaments and 1.2 watt for the quartz filaments.

A satisfactory method of protection was afforded by sealing the fibres, after soldering to wire terminals, in glass tubes and an example of this type is given in Fig. 2(b). Specimens were also set in a number of proprietary casting resins but these materials proved unsuitable for protection because of the large differences in expansion of the fibres and the resins, breakage of the fibres occurring at elevated temperatures. On testing, the protected resistors showed smaller changes in resistance after climatic cycling than the unprotected samples and, in general, dissipated greater wattages before breakdown occurred, some filaments becoming red-hot before breakage.

It is concluded that glass and quartz fibres can be satisfactorily metallized by the firing-on process, the filament resistors possessing many useful properties. With the aid of a suitable machine, considerable lengths could be metallized and these may offer an alternative to the fine resistance wires used in the production of high value resistors.

Variable Resistors on Glass Plates

The double-firing process is suitable for the production of variable resistors since almost any pattern can be scribed with a sharp metal point while the films are in the semi-fired state. Two suitable patterns for these resistors are given in Fig. 1. The pattern of Fig. 1 is useful where stepless elements of low resistance are required and an example

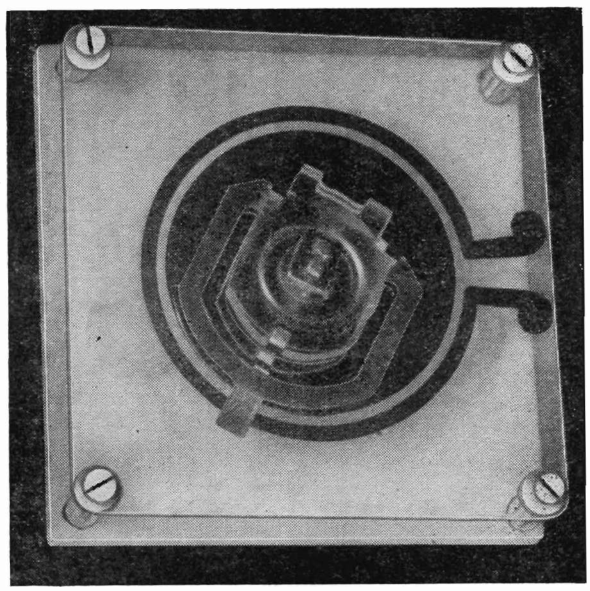


Fig. 3. Working model of a variable resistor on a glass plate 2 inches square, resistance value 200 ohms.

of a working resistor made to this pattern on a glass plate is shown in Fig. 3. For higher value resistors the pattern of Fig. 1(c) is more suitable, this track being a modification of the "meandering" technique used for the fixed resistors on flat plates.

Clearly, considerable work has yet to be done in determining the most suitable alloy for the thin film elements as regards wear resistance and the best contact material. Experimental samples have indicated, however, that these resistors possess advantages over the carbon and wire-wound variable resistors at present in use. The output from a potentiometer made to the pattern of Fig. 1(b) is continuously variable and may be useful in an application requiring high stability elements of flow resistance. The absence of a high resistance oxide on the surface of the noble metal films allows lower contact pressures than are usual in the wire-wound type of resistor. Consequently, friction is reduced on the rubbing surfaces and the torque required for operation is low. In addition, the resistances are stable without protection, their noise level is low and their flat form allows high wattage dissipations.

Conclusions

It has been shown that thin noble metal films can be used to provide useful resistors of both the fixed and variable types which embody most of the properties expected of high grade components. Working models of some of the many likely forms have been made, and, on testing, these proved to be both stable and reliable over a wide range of resistance values.

The cost of the precious metals used is not prohibitive since the quantities involved are very small. An alternative to the mechanical engraving operation used in the meandering on flat plates would, however, reduce production costs and an etching process using photo-mechanics is suggested.

Metal film resistors may find applications where the existing types are unsuitable, their variety of form offering numerous alternatives. As potentiometer elements of low resistance with step-less outputs, they may be of value for measuring-apparatus where low inductance, high stability and low noise are important. The metallized fibres may be useful where miniature high value resistors are required and the flat-plate resistors may be adapted to printed-circuit techniques.

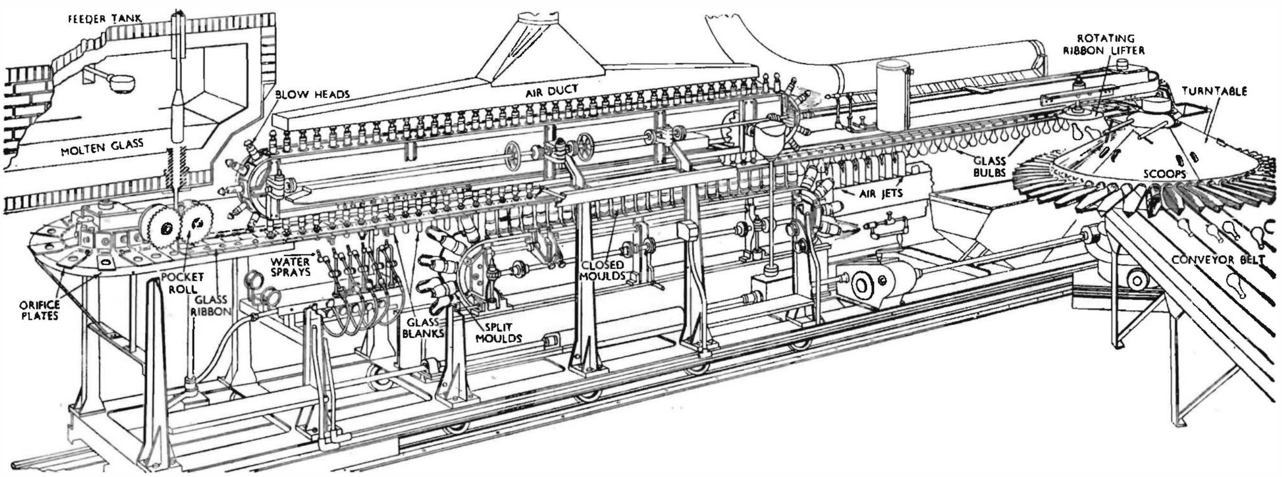
Acknowledgment

In concluding, the author wishes to thank the Chief Scientist, Ministry of Supply, for permission to publish this article.

A New Method for the Quantity Production of Glass Bulbs

GLASS bulbs of a great many different types and sizes are required in vast quantities by the lamp and valve industries. Up to twenty-five years ago they were all made by skilled hand blowers, but since that time various automatic machines have been in use which are capable of producing bulbs in considerable quantities. However, the increasing demand both from home and overseas markets has made it necessary to undertake production on a scale never previously contemplated. Accordingly The British Thomson-Houston Co., Ltd., and The General Electric Co., Ltd., have jointly formed a new company, Glass Bulbs Ltd., with a factory at Harworth, near Doncaster, Yorkshire, which is capable of producing one-and-a-half million glass bulbs a day. This vast production has been made possible by the installation of two ribbon-type machines which are the only ones of their kind outside the United States.

An important characteristic of the ribbon machine is that it is much more versatile than any other bulb blowing machine. It will blow the miniature type of valve bulb at a very high



speed and can be quickly turned over to the production of large size filament lamp bulbs. A further important feature is the consistency of the product and its constant dimensional accuracy which greatly exceeds that previously obtainable from any other machine.

The larger machine produces from 350 to 500 bulbs a minute in the 70 mm, 75 mm and 80 mm sizes for 75 watt, 100 watt and 150 watt general lighting service lamps. Operating on a continuous 24 hour schedule, this machine gives a daily output of approximately 500,000 bulbs. The smaller machine will produce the whole range of valve bulbs up to 44·5 mm diameter, including all the miniature types, and lamp bulbs from the 25 mm size to the 65 mm bulb for the 60 watt general service lamp. The output of this machine, which runs continuously throughout the 24 hours, is approximately 1,000,000 bulbs daily.

Operation of the Ribbon Machine

A controlled stream of molten glass is made to flow from the forehearth down between two rotating water cooled rollers at one end of the ribbon machine shown in the outline diagram. One roller has a plain surface, the other contains pockets, or circular depressions, so that the glass issues from between them as a continuous ribbon bearing a series of shallow circular protuberances or "humps." On leaving the rollers the ribbon is carried on a continuous belt of orifice plates, each of which is pierced with a circular hole that comes accurately into position beneath a "hump." Moving forward on the orifice plates the ribbon now meets a continuous chain of blowheads which descend on to it from above, each blowhead pressing into the centre of a "hump" directly over a hole in each orifice plate.

A puff of compressed air issuing from the blowhead causes the "hump" to be extruded downwards through the hole in the orifice plate, the function of which is to determine the diameter of the flare at the top of the neck of the finished bulb. These glass blanks hanging below the rapidly moving ribbon, increase in depth until they meet the split moulds which rise from below on a continuous belt and close round them from both sides. The moulds now begin to rotate and meanwhile the air pressure from the blowheads increases so that the glass blanks are moulded to their final shape. It will be understood that during this operation the ribbon, blowheads and moulds are all moving forward together at the same speed. On completion of this process the moulds open, revealing the bulbs and return on their belt under the machine. Similarly the blowheads break contact with the glass ribbon and return along the machine on the upper side of their chain. The orifice plates, carrying the ribbon with the blown bulbs depending from beneath it, continue to travel forwards while jets of cooling air play upon the completed bulbs. On reaching the rotating ribbon lifter the bulbs are successively tapped off by the strokes of a synchronized hammer and fall into the scoops of a rotary turntable which tip them on to a moving belt for conveyance through a gas-fired lehr, or annealing oven. The glass ribbon passes down to the floor below where it is watercooled and subsequently broken up for re-use as cullet, while the orifice plates return horizontally behind the machine.

Mean-Noise Characteristics of Glow-Discharge Voltage-Regulator Tubes

By H. Bache,* B.Eng., and F. A. Benson,* M.Eng., A.M.I.E.E., M.I.R.E.

VERY little information was available until recently on the noise characteristics of glow-discharge voltage-regulator tubes. Many tube specifications make no mention of such characteristics and those that do, usually quote only a single value. The authors have now examined a number of tubes of several different types to determine their peak-noise and mean-noise characteristics. The results of peak-noise measurements for 15 different types of tube have already been published,[1] from which variations in peak-noise with tube current, from tube to tube of similar or different designs, from operation to operation with a single tube, with life, or with the effective load can be determined. This article gives the results of mean-noise measurements which have been carried out to provide similar information for 6 different types of tube, viz.: 85A1, 85A2, 7475, NT2, VR105 and VR150.

In many cases the tubes of a particular type were not all from the same batch or of the same construction,

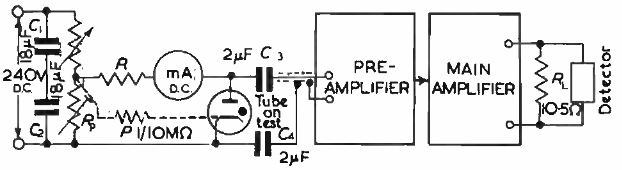


Fig. 1. The circuit used for test
Primer circuit for G180/2M tubes shown dotted

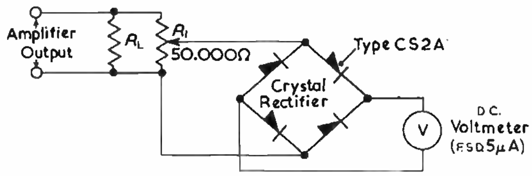


Fig. 2. The detector circuit.

because they were obtained at intervals over a period of two years and modifications in design were made by the manufacturers from time to time.

Procedure

The mean-noise measurements were made with a similar calibrated amplifier-detector unit used for the peak-noise examinations, having a perfectly linear response curve over the frequency range 300-20,000c/s and an input admittance of the order of 0.6 micromhos. The circuit arrangement used is shown again in Fig. 1 and the detector circuit in Fig. 2. As in the previous work the D.C. supply for the tubes was obtained from a separate H.T. accumulator. The tube current was varied, in each case, throughout its specified range and the mean-noise value recorded. After each change of current, time was allowed for the tube to settle down again to steady conditions before a further noise reading was taken.

Results

The mean-noise characteristics of nearly new tubes of the 6 types examined are shown in Figs. 3, 4, 5, 6 and 7. The tube current has been reduced in each case below the specified minimum value and the noise recorded. For each tube the mean-noise has been noted for several operations, thus, a very large number of readings have been obtained for each type of tube, and in order to make the Figs. clear, only the limits have been drawn. Variations of the mean-noise characteristics with life have been determined for the tube-types 7475, 85A1 and 85A2. Fig. 8 shows these variations for the 7475 type. No similar curves have been drawn for types 85A1 and 85A2 because there is no measurable change of mean-noise

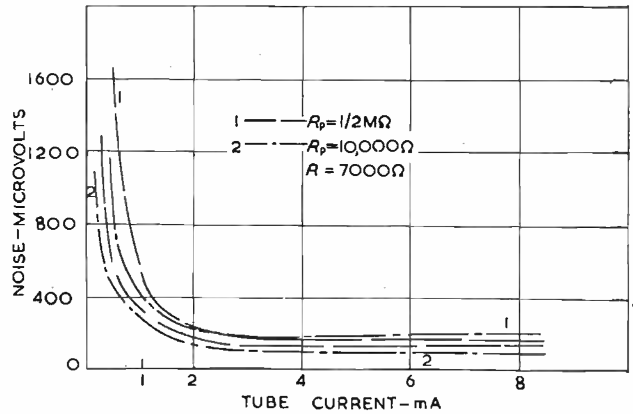


Fig. 3. Tube type 7475.

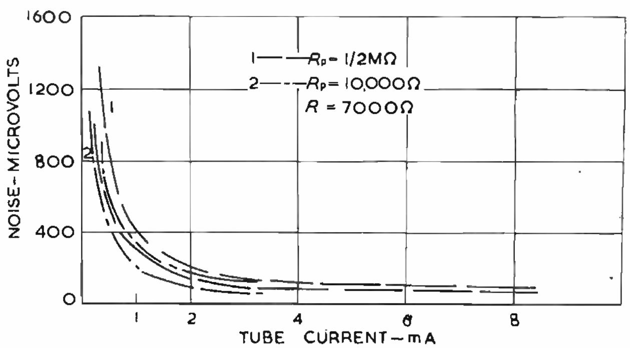


Fig. 4. Tube type 85A1.

characteristics with life (at least when run continuously at 5mA up to 20,000 hours for 85A1 and 7,000 hours for 85A2).

Discussion of Results

As in the case of peak-noise work it is found that the mean-noise characteristics of all the types tested, at any stage in their life, follow the same general form. Hence, it is reasonable to assume that all the types previously tested for peak-noise behave similarly, due to the similarity in their peak characteristics. The noise increases with decreasing tube current and increases very quickly as the region of minimum current is approached. As found before, the characteristics of a given tube are nearly reproducible.

* *University of Sheffield.*

The variations in the mean-noise characteristics from tube to tube of a similar design are not very great; in fact, the variations from type to type are again less than might be anticipated from data obtained on other tube characteristics, also remembering that the tubes have widely different constructions, gas fillings, gas pressures and electrode materials.

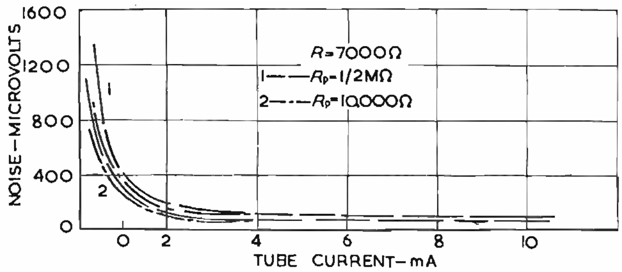


Fig. 5. Tube type 85A2.

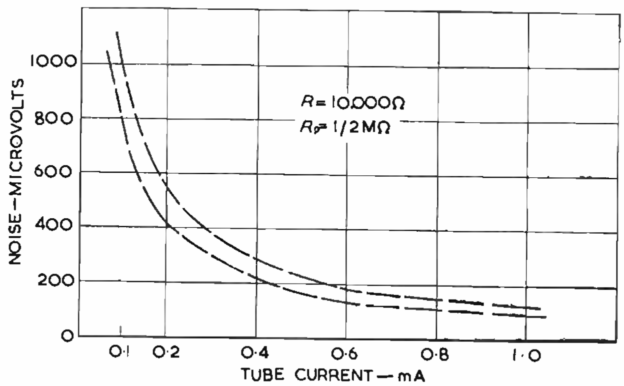


Fig. 6. Tube type NT2.

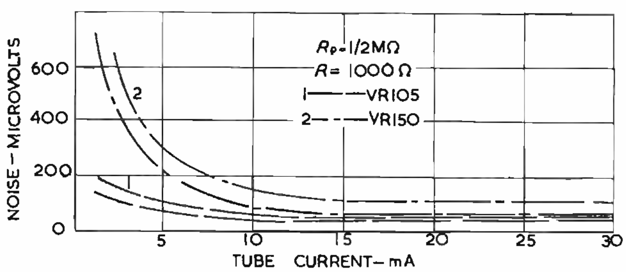


Fig. 7. Tube types VR105 and VR150

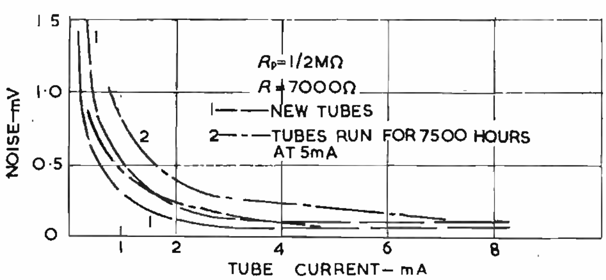


Fig. 8. Tube type 7475.

The effect of varying resistor R_p (Fig. 1) on the mean-noise characteristics of tubes types 7475, 85A1 and 85A2 can be seen from Figs. 3, 4 and 5 respectively. As for peak-noise values, the noise decreases as R_p is reduced.

Curves 1 and 2 on Fig. 3 correspond with the previous curves 1 and 3 on Fig. 2 already published.[1] It should be noted that there is not as great a divergence in the limits of noise at low currents for peak as for mean values as R_p varies. The divergence of the limits at high currents is much the same for both peak and mean values. This suggests that the noise waveform changes as the tube current is varied. It will also be found of interest to compare the corresponding curves of Fig. 7 and the previously published ones of Fig. 4[1] for the VR105 and VR150 tubes.

Fig. 8 and the previously published Fig. 6[1] show the variations of mean and peak-noise characteristics respectively with life for 7475 tubes. At the top of the current range there is a large change of peak-noise with life but not of mean-noise. Thus, it appears that the noise waveform also changes with life for these tubes during the 7,500 hours of operation.

It is interesting to note the relative values of peak and mean-noise for a given type of tube and to see whether, if one of these values is known, the other can be estimated. For the almost-new tubes tested it is found that when $R_p = \frac{1}{2}M\Omega$ the ratio of peak to mean-noise values increases as tube current decreases. However, it decreases as tube current decreases when $R_p = 10{,}000\Omega$. This suggests a condition where a certain value of R_p gives an approximately-constant value for the ratio, but work to confirm this has not been undertaken at this stage. For the 7475 tubes which have been life tested, it is found that the ratio decreases as tube current decreases when $R_p = \frac{1}{2}M\Omega$. It should be pointed out that the change in the ratio is somewhat erratic and only "tendencies" are implied in the above statements.

It is hoped that, in view of the information obtained by the authors, tube specifications will now be modified so as to quote approximate limits for both peak and mean-noise voltages to be expected throughout the current range of a tube.

Acknowledgments

The work recorded in this paper has been carried out in the Department of Electrical Engineering at the University of Sheffield. The authors wish to thank Mr. O. I. Butler, M.Sc. M.I.E.E., A.M.I.Mech.E., for facilities afforded in the Laboratories of this Department. They also wish to acknowledge the kindness of Mullard Ltd., in supplying some of the tubes for test.

REFERENCE

1. Bache, H. and Benson, F. A. Peak Noise Characteristics of Glow-Discharge Voltage-Regulator Tubes. *Electronic Engg.* *24*, 278 (1952).

The London Radio-Telephone Terminal

At the new London Radio-Telephone Terminal at Brent Buildings central technical control is provided for all overseas radio-telephony circuits.

The technical operator controls each radio circuit and is technically responsible for its satisfactory operation.

The technical operator's position provides monitoring and level measuring facilities and enables the operator to insert and control the various voice-operated and noise-reducing devices and privacy and channelling equipment required. It also provides communication to the overseas exchange and radio stations.

The operating positions are remote from the apparatus bays and each position is equipped to enable one operator to control up to four radio circuits. Under certain conditions the operating positions may be left unattended and the circuits extended to a concentrator position which provides monitoring facilities for all circuits on the six positions in the suite.

This equipment has been designed by the Radio Branch, Post Office Engineering Department and manufactured by Whiteley Electrical Radio Co., Ltd., Mansfield, Notts.

Millimicrosecond Pulse Techniques

(Part 4)

A Multi-Channel Delayed Coincidence Analyser

By G. R. J. McLusky,* B.Sc. and N. F. Moody,† A.M.I.E.E.

Part 1 of this series of articles described basic techniques and circuits, while Parts 2 and 3 showed how these techniques could be applied to a high speed oscilloscope and to a time expansion system. The present section deals with the use of high resolution coincidence mixers in nuclear physics, and describes the development of a multi-channel coincidence mixer system used in delayed coincidence analysis.

MEASUREMENTS in nuclear research are made upon "events" which are random in nature, since each arises from a spontaneous change in one of the observed nuclei. Such radioactive events are detected when the particle or ray emitted as a result of the nuclear change (β particles and γ-rays in the work here described) traverses a suitable detector and generates an electrical impulse. It may be necessary to observe one particular radioactivity in the presence of intense interfering radioactive fields, either natural or induced. In some instances the detector can be so arranged that the amplitude of the pulse produced is related to the type of incident radiation and its specific energy, so permitting both measurement of the energy and rejection of "background" pulses corresponding to unwanted radiations. Alternatively a coincidence mixer can be used to identify the desired event by time correlation. For this purpose either a single radiation must be made to operate two detectors simultaneously, or the event concerned must be such as to produce two separate radiations which can be made to strike a pair of detectors. Then the interference, if occurring randomly in each detector, has a much smaller probability of scoring.

It is possible for each event to leave the nucleus concerned in an unstable or "excited" state, which ends in the emission of a second particle or ray. Under such circumstances the time-delay between the two radiations will not be unique and is predictable only on a statistical basis for a large number of radiation pairs. It is described by such terms as the "mean lifetime" or "half-life" or "decay exponent" of the excited state. The rate of occurrence of pulse pairs of specified separation time and arising from such an excited state follows a known statistical law: it will vary exponentially with the time of separation, and the time-constant of the exponential is characteristic of the particular excited nucleus. Thus coincidence mixers allow not only the required correlation to minimize background, but, if fitted with a variable delay, can be used to measure the mean lifetime. It is the latter aspect with which this article is primarily concerned.

The introduction of scintillation counters has made it possible to extend the techniques into the millimicrosecond range, and delayed coincidences on this time scale have been observed[1] by interposing a series of different lengths of delay cable between the two detector units and the coincidence mixer, and recording the corresponding coincidence counting rates. If the coincidence mixer had a resolving time very much shorter than the half-life $T_{1/2}$ concerned, and all the pulses were of equal amplitude, then the plot of coincidence counting rate against relative delay would be an exponential decay, as shown in Fig. 1(a). However, when the system is being used at its limit, to investigate the shortest possible half-lives, then the mixer resolving time will become comparable with $T_{1/2}$. The result then obtained can best be understood by first considering the conditions when the pulses at the two detectors are precisely coincident, but the pulse amplitudes are variable, as is found in practice. The plot of coincidence counting rate against relative delay will be as Fig. 1(b), and the shape and width $2T_0$ of this curve will be characterestic of the particular coincidence mixer concerned.

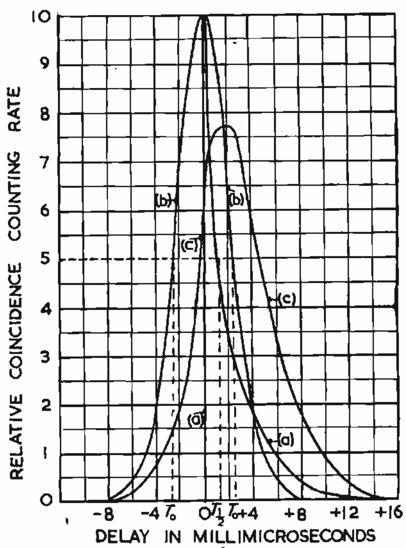


Fig. 1. Coincidence resolution curves

(The expected rectangular shape is degraded due to variations in input pulse amplitudes at the two detectors. This phenomenon is discussed more fully later in the paper.) It can be shown that if a mixer of such a characteristic is supplied with pulses following the law of Fig. 1(a), then the resulting counting-rate against time plot will be as Fig. 1(c). In effect, curve (a) when "operated on" by curve (b) produces curve (c). Mathematical techniques are available[2] for analysing experimental results of the form (b) and (c) to calculate the half-life; one simple result is that the horizontal distance between the "centres of gravity" of the areas of the two curves is equal to the mean life of the excited state, i.e., 1·44 × half-life. It has been shown[3] that when $2T_0$ = 5·5mμsec, a half-life of 0·5mμsec is easily detectable, provided, of course, that the shape and position of the mixer's inherent response does not vary from any other cause during the series of observations.

* National Research Council, Canada.
† Ministry of Supply, England.

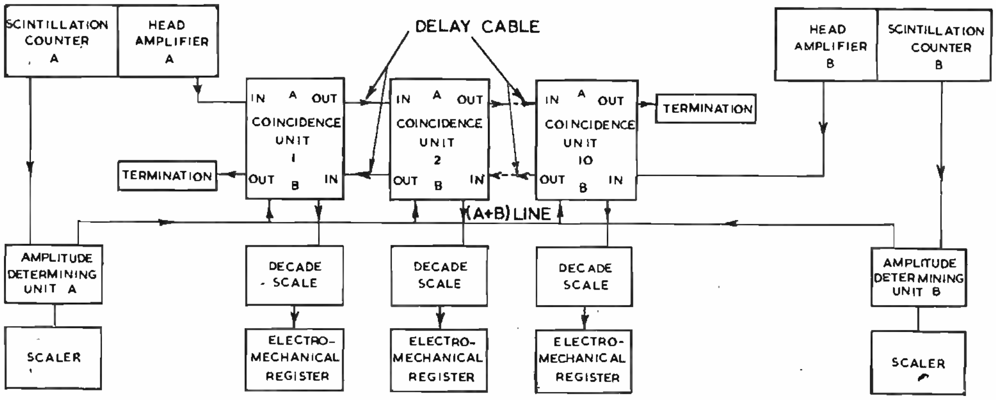


Fig. 2. The ten channel delayed coincidence system

a negative signal to the corresponding amplitude determining units, whose function will be explained later.

Signals from the two head amplifiers are fed in opposed sequence through the series of identical coincidence mixers, the lengths of interconnecting 75 ohm coaxial cable being chosen to give the required relative delay. Since each channel is arranged to absorb negligible power from the input, there is no appreciable attenuation of the signal.

By employing a motor driven mechanism to change the relative delays in the two inputs in a suitable sequence, such a series of observations can be performed automatically[4], the complete experiment extending over many hours if necessary.

A Multi-Channel Coincidence Analyser

For many purposes (e.g. when the radioactive source has a half-life less than an hour) it would be advantageous to use a multi-channel system, consisting of a number of separate coincidence mixers, each with different signal delays between it and the two detector units. Then, provided the different channels have identical characteristics, the coincidences recorded by each would give one point on a delay versus counting-rate curve such as Fig. 1(c). Such a system has been constructed, and its block diagram is given in Fig. 2. The detectors are scintillation counters, employing stilbene crystals viewed by 1P21 photomultipliers. The latter operate at voltages up to 2kV, so delivering an output pulse current sufficient to swing the input capacitance of the head amplifier by at least 3 volts in approximately 1mμsec. Each head amplifier consists of a single Western Electric 404A valve (12mA/V, 7pF input),* whose grid receives positive drive from the last dynode of the photomultiplier, and whose anode feeds the corresponding 75 ohm concentric line systems. The head amplifier delivers at least 3 volts of negative signal, having a rise time of about 1mμsec and duration greater than 50mμsec. The anode of each photomultiplier also gives

* *For further data on this valve see Part I.*

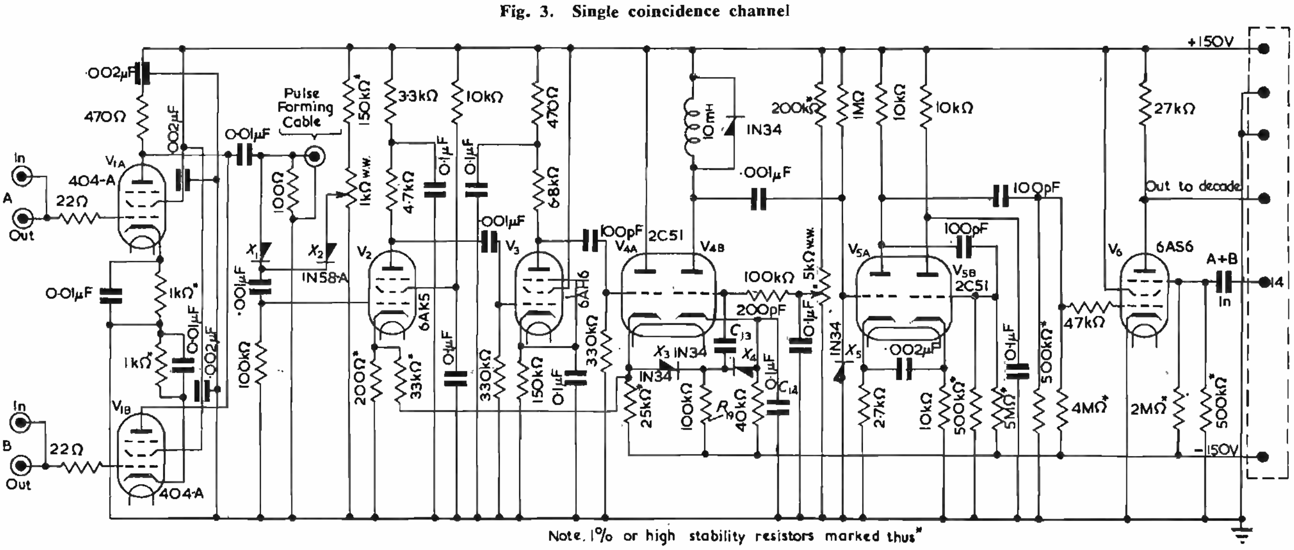
Fig. 3 gives the circuit of a coincidence channel. V_{1A} and V_{1B}, both 404A valves, act as isolating and limiting amplifiers, their grids being directly connected to the input concentric line systems, which are maintained at a mean potential of 25 volts above ground. Since these valves have 1kΩ cathode resistors they operate at a closely controlled cathode current of 26mA, with 20mA of anode current. The common anode load consists of a length of 75 ohm coaxial cable which is terminated at the anode end and shorted at the far end, so that when either valve is cut-off a square wave is produced of defined amplitude and of duration T_0 equal to twice the electrical length of the cable. If, then, the two valves are cut-off at instants separated by a time T, the resulting square waves at the anodes will be superimposed, as shown in Fig. 4, rising only to 0·75 volt if the inputs are non-coincident (i.e., $T > T_0$) but rising to 1·5 volts for a time δT if $T < T_0$.

The rates of rise and fall of this waveform are, of course, limited by the total capacitance from the anodes to ground. The crystal diode X_1 is biased, by means of X_2, so that it does not conduct until its anode has risen by more than 0·75 volt, i.e. when a coincidence has occurred. Then the current through X_1 charges the grid capacitance of V_2, the first valve of the linear amplifier, to a voltage which depends on the ratio of δT to the time-constant formed by the input capacitance and the diode forward resistance.

It will be seen that, for this system, the process of coincidence mixing can be divided into three parts:

(1) From the front edge of the input signals, them-

Fig. 3. Single coincidence channel



Note. 1% or high stability resistors marked thus*
Crystals – Sylvania U.S.A.

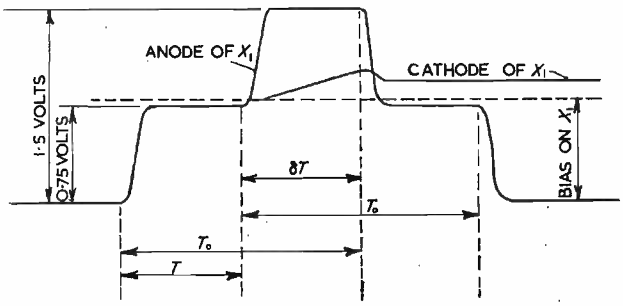


Fig. 4. Coincidence unit waveforms

selves of indeterminate length, square waves of determined length and amplitude are formed.

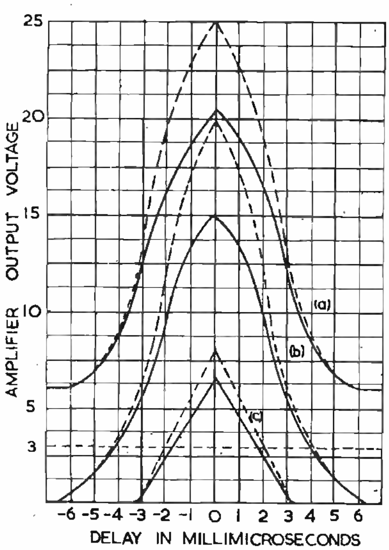
(2) These square waves are added linearly, giving a double amplitude signal when in coincidence.

(3) The resultant signal is applied to a non-linear element in such a way that amplitude discrimination is obtained, and an output occurs only for coincident inputs.

For the formation and addition of very short pulses, low impedance circuits must be used; since only limited valve current is available low voltage levels are inevitable. The germanium diode is therefore the best choice as amplitude discriminator, since its impedance changes by a factor of 10 for only 0·07 volt in the forward direction. It is necessary to preserve very high bandwidth only to the point where the two signals are added and the amplitude discrimination performed; beyond that point the bandwidth can be degraded to a degree limited only by the counting rate required.

The linear amplifier V_2, V_3, V_4 has a gain of 150, and as is seen from Fig. 3 its design is conventional apart from the final amplitude discriminator.* Valve V_{4A} acts as the output cathode-follower for the linear amplifier, while as far as D.C. levels are concerned V_{4B} also acts as a cathode-follower to supply a low impedance bias point for the cathode of X_4, the amount of bias being adjusted by the 5kΩ potentiometer in V_{4B} grid circuit. When, in response to a signal the cathode of V_{4A} has risen far enough to overcome the discriminator bias X_3 will conduct, giving a pulse through the capacitor C_{13} to the grid of V_{4B}. In the quiescent condition 1·5mA is drawn through X_4 by R_{19}, and since the stray capacitance across X_3 is only 1pF, the pulse can have a rate of rise up to 1·5 volts per mμsec without capacitance break-through. In passing it is to be noted that the circuit will automatically compensate for identical changes in the grid to cathode potentials of V_{4A} and V_{4B} due to change in heater voltage. Since the cathode of V_{4B} is grounded by C_{14}, while the choke in its anode circuit presents a high impedance, the pulse reaching V_{4B} grid is amplified and drives the cathode coupled trigger circuit V_{5A} and V_{5B}, producing a 5μsec positive pulse at the grid of the gate tube V_6. Provided that at the same instant a similar pulse derived from the amplitude determining units (to be described) has arrived at the third grid of the same tube, a negative pulse from its anode drives the decade scaler and records a coincidence.

Fig. 5. Response of coincidence circuit



* *The "linear amplifier" as employed in nuclear research usually includes a discriminator.*

Since the bandwidth of the linear amplifier is only about 5Mc/s the amplitude of the output pulse at V_{4A} cathode depends both on the amplitude and duration of the input. Of these two quantities, the amplitude is determined by the over-lap of the original coincident pulses (i.e. by δT in Fig. 4) and by the bias on diode X_1, while the duration is determined by the time-constant of the total capacitance on the grid of V_2 and the total leakage from that point to ground; i.e. the diodes' back resistance in parallel with 100kΩ. It should be noted that after heavy conduction, a germanium diode has an abnormally low back resistance for about 1μsec and also that the back resistance varies with ambient temperature. The basic coincidence circuit was tested by varying the relative timing of the input pulses (derived from a mercury-relay pulse generator, and

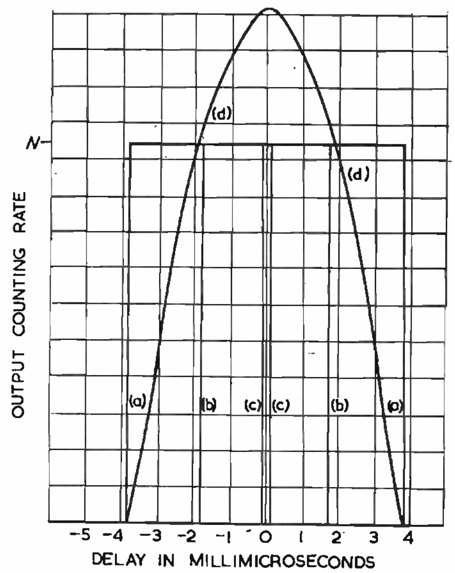


Fig. 6. Response of coincidence mixer to varying input pulse amplitudes

of a constant amplitude sufficient to cut off V_{1A} and V_{1B} completely), and recording the resulting variation of the pulse amplitude at V_{4A} cathode. The pulse forming cable had an electrical length of 2mμsec giving T_0 = 4mμsec and the results are shown in Fig. 5, where curves (a), (b) and (c) correspond to the X_1 bias being, respectively, too low, correct, and too high. In each instance the dotted line was obtained immediately the unit was switched on, and the full line refers to conditions at normal operating temperature. It is seen that with optimum bias on X_1 (as for curve (b)) and the final amplitude discriminator set to 3 volts, the complete mixer responds only to pulses coincident within ±3·8mμsec and that this resolution is not varied by more than 0·1mμsec by change in temperature.

Consequently, when the input pulse pairs have a repetition rate of N per minute, the plot of counting rate at V_5 against relative timing of input pulses is as shown in Fig. 6(a). If the amplitude of the test pulses is reduced so that they are not sufficient to cut-off V_{1A} and V_{1B} completely, then the square waves at the common anode are of reduced amplitude, causing the unit to behave as though the bias on X_1 had been increased, as for Fig. 5(c). As a result the delay/counting-rate plot is changed to Fig. 6(b). If the pulse amplitude had been further reduced, a limiting condition would be reached when the unit responded only to precisely coincident pulses, as for

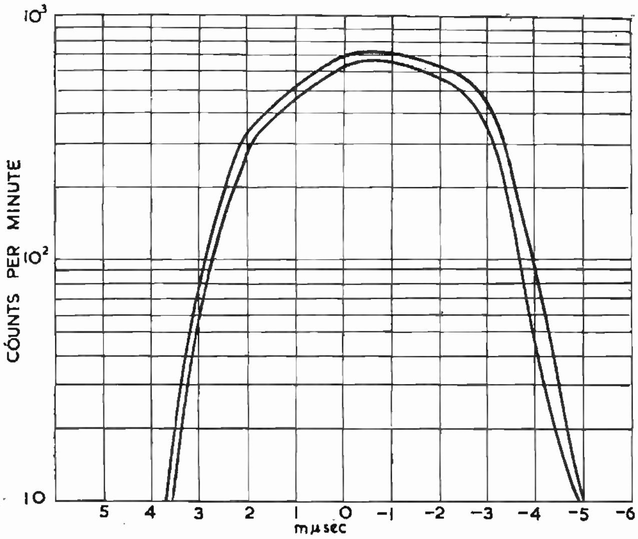
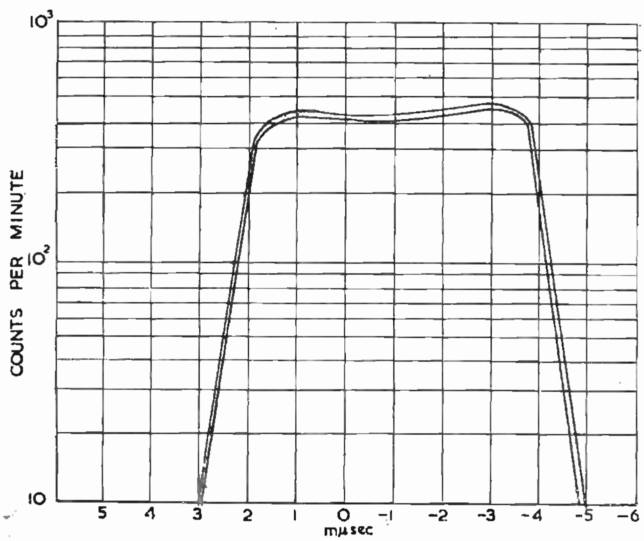


Fig. 7. Coincidence mixer response

Fig. 6(c). The actual output pulses of a scintillation counter have a considerable spread in amplitude and, when a coincidence mixer is driven from such a source, its behaviour can be considered as being due to the addition of a large number of characteristics of which Fig. 6(a) and (c) represent limiting conditions, and a response as Fig. 6(d) results (cf. Fig. 1(b)). This effect is aggravated if the input pulses have a rate of rise comparable with the desired resolution; a smaller pulse will take proportionately longer to traverse the grid-base of V_1, and so will appear "later".

The inclusion in each head amplifier of a high-speed amplitude discriminator and trigger circuit would not improve matters, since such a unit would introduce an additional time delay which was itself a function of pulse size, becoming relatively large for pulses which were only just sufficient to trigger the circuit. However, the required improvement is achieved by separately measuring the amplitudes of the input pulses in relatively slow acting circuits, and then recording only those coincidences which corresponded to input pulses inside the chosen amplitude limits. This function is performed by the amplitude determining units, each of which has adjustable upper and lower amplitude discriminators, and acts as a single channel pulse amplitude analyser[5] of conventional design. Thus an output pulse is produced only when the input lies between

Fig. 8. Coincidence mixer response



the prescribed limits. A coincidence between the outputs of the two amplitude-determining units causes a 5μsec positive pulse to appear on the $(A + B)$ line (see Fig. 2 and Fig. 3, terminal 14), so allowing any unit which has detected a coincidence to pass its output pulse into the corresponding decade scaler. In addition, separate scalers driven by the amplitude-determining units record the number of pulses which have been accepted for possible coincidences.

Four coincidence units were tested by re-connecting the input cables so that both input pulses travelled in the same direction along the system, and there was therefore no relative delay between units. Exactly coincident inputs were obtained from a pair of photomultipliers mounted so that their photocathodes were illuminated by opposite sides of a single stilbene crystal, which was irradiated by γ rays from a radium needle. Then, by varying the lengths of cable between the head amplifiers and the remainder of the system, the responses of all four units were plotted simultaneously, as shown in Fig. 7 and Fig. 8, in which for greater clarity only the extreme characteristics are drawn, the other two curves in fact lying between them. The pulse-forming cable length was 2mμsec giving $2T_0$ of 8mμsec ideally.

For Fig. 7 the amplitude limits were set to accept coincidences from pulses lying between 27 and 3 arbitrary units (where about 6 units were required to fully drive the input valve of a coincidence unit); this result should be compared with Fig. 6(d), noting that in Fig. 7 the counting-rate scale is logarithmic. For Fig. 8 (cf. Fig. 6(a)) the amplitude limits were 27 and 11, and the effective source strength had to be increased by a factor of 50 to achieve a comparable counting-rate, since now a higher proportion of the coincidences were being rejected by the action of the amplitude-determining units. For these tests the final discriminator bias was preset at 3 volts, while the bias on the first diode X_1 (which was available as a front-panel control) was adjusted to make the units give substantially the same counting rate at +2mμsec in the conditions of Fig. 8, and then both sets of results were plotted without further readjustment. No appreciable drift in the characteristics with time was observed.

In some instances it is required to select the input pulses in amplitude so as to correspond to one particular energy of incident radiation or particle, quite apart from the amplitude requirements of the coincidence mixer itself. It is for this reason that an upper as well as a lower amplitude limit was incorporated in the amplitude-determining units. By reducing the lengths of the pulse-forming cables, the resolving time $2T_0$ of each channel can be reduced at least to 1/2mμsec, provided that the rate of rise of the input signals can be increased in proportion.

The technique of using a single high resolution coincidence mixer in combination with two separate slower acting amplifiers and amplitude discriminators, with the outputs combined in triple coincidence, was devised by Dr. R. E. Bell of these laboratories.

Acknowledgment

In conclusion the authors wish to make acknowledgment for permission to publish as follows:—

Parts 1, 2, and 4; National Research Council of Canada.
Part 3; Chief Scientist, Ministry of Supply, England.

REFERENCES

1. Bell, R. E. and Petch, H. E. Upper Limit for the Lifetime of the 411-Kev Exited State of Hg^{198}. *Phys. Rev. 76*, 1409 (1949).
2. Newton, T. D. Decay Constants from Coincidence Experiments. *Phys. Rev. 78*, 490 (1950).
3. Bell, R. E. and Graham, R. L. Measurement of a Second Half-Life in Yb^{170}. *Phys. Rev. 78*, 490 (1950).
4. Bell, R. E., Graham, R. L. and Petch, H. E. Design and use of a Coincidence Circuit of Short Resolving Time. *Canadian Journal of Physics*. January, 1952.
5. Moody, N. F., Battell, W. J., Howell, W. D. and Taplin, R. H. A Comprehensive Counting System for Nuclear Physics Research. *Rev. Sci. Inst. 22*, 551 (1951).

An Exponential Stimulator

By A. M. Andrew,* B.Sc.

THE nerve stimulator to be described provides pulses of current of three seconds duration, each pulse being initiated by pressing a push-button. The stimulator may be set to give either an abrupt rise of current or a rise according to the equation

$$I = I_0\left(1 - e^{-t/\alpha}\right) \qquad (1)$$

where α can be selected. With either type of rise, the final current I_0 is adjustable by means of two decade switches, in steps of 0·1mA up to a maximum of 10mA.

An additional feature is the exceptionally high output impedance. The output current is practically independent of the resistance of the biological preparation over the range of resistance values likely to occur.

Purpose of the Stimulator

Nerves are more readily stimulated by an abruptly rising current than by one which rises gradually, because with the gradual rise the nerve has time to "accommodate" while the current is rising.

Using the stimulator, the minimum current which will stimulate with an abrupt rise may be found. This current (the pulses being of long duration) is known as the rheobase. Then for some value of α, the minimum exponentially rising current which will stimulate may be found. The ratio of this current to the rheobase depends on the rate of accommodation of the nerve. A graph of this ratio R against the time-constant α is known as the "accommodation curve" for the nerve.

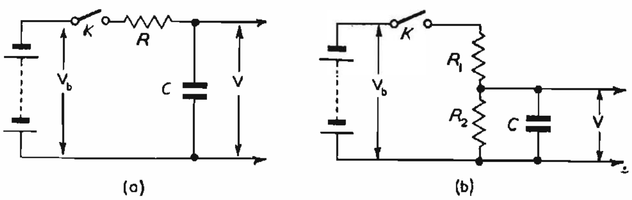


Fig. 1. Circuits which produce exponentially rising voltages

Forms of current rise other than that represented by equation (1) might have been used, but this form is used because it is easily produced, and has been used by previous workers.

A number of workers[1,3,7,8] have studied the accommodation of nerves using current of this form, and Kugelberg[3] in particular has used it in a thorough investigation of accommodation in human nerves. Skoglund[6] has pointed out that for certain purposes a linearly rising current is preferable, and this has also been used[4,6]. A mathematical theory of nerve excitation has been put forward by Hill[2].

The stimulator was developed primarily for the stimulation of human nerves by means of electrodes on the skin. The ulnar nerve, for instance, can be stimulated through a small electrode (the negative one), covered with a saline-soaked pad, placed over the nerve at the elbow, and a large neutral (positive) electrode on the forearm. Stimulation is indicated by the twitching of a muscle supplied by the nerve.

The exact values of stimulating current have no significance, since they depend on electrode placement (which determines the fraction of the current which actually flows through the nerve), and measurements of them are not reproducible. Measurements of the ratios as described above are reproducible, provided the determination of rheobase is made within a short time of the determination of minimal exponentially rising current, care being taken not to move the small electrode between the determinations.

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Producing the Waveform

A voltage varying according to the equation:

$$V = V_0\left(1 - e^{-t/\alpha}\right) \qquad (2)$$

is generated by the circuits of Fig. 1(a) and (b), if switch K is closed at time $t = 0$.

For the circuit of Fig. 1(a), $V_0 = V_b$ and $\alpha = RC$

For the circuit of Fig. 1(b), $V_0 = V_b \dfrac{R_2}{R_1 + R_2}$,

$$\alpha = \frac{R_1 R_2}{R_1 + R_2} C$$

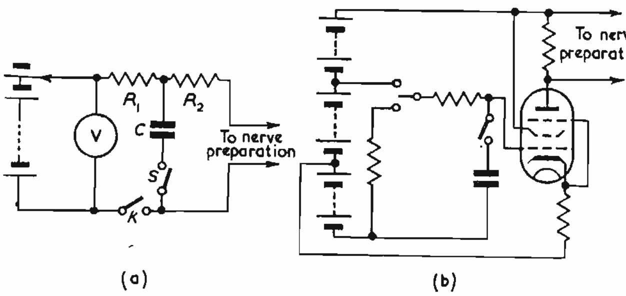


Fig. 2. Stimulators used by other workers

The stimulator used by Solandt[7] was essentially that of Fig. 2(a). The stimulus is applied when switch K is closed. An abrupt rise of current is obtained if switch S is open, and a rise according to Equation (1) if S is closed, the time-constant α being given by:

$$\alpha = \frac{R_1(R_2 + R_p)}{R_1 + R_2 + R_p} C \qquad (3)$$

where R_p is the resistance of the preparation.

The time-constant, and also to a large extent the output current, can be made independent of the preparation resistance by interposing a valve stage between the circuit of Fig. 1(a) and the preparation, as in Fig. 2(b). A stimulator of this type was used by Bernhard, Granit and Skoglund[1] and by Kugelberg.[3] The valve is initially biased to cut-off. The cathode resistance is incorporated to reduce distortion due to curvature of the valve characteristics.

Timing Flip-flop

The circuit of the author's stimulator is shown in Fig. 3. The power unit is conventional, except that the line which would normally be at +450 volts (unstabilized) is earthed. A metal rectifier is used to supply −400 volts with respect to the −450 volt line (i.e. centre tap of the H.T. winding). V_2, V_3, and V_4 form a conventional stabilizer supplying

−100 volts and +200 volts with respect to the −450 line. A simpler circuit, with two 7475 valves in series, could have been used to supply +200 volts.

Instead of the mechanical switch K in Figs. 1 and 2, V_5 is used in a flip-flop circuit which eliminates transients due to contact bounce, and makes the duration of the stimulating current constant and independent of the operator's judgment. The right-hand section of V_5 is initially biased beyond cut-off, and no voltage appears across its anode load. When the circuit is flipped by pressing PB_1, this section draws grid current, so the grid-cathode P.D. is approximately zero. With zero bias, one half of a 6SN7 triode conducts roughly as if it were a resistor of 10kΩ. Hence the right-hand section, with its anode load of 470kΩ, behaves as a generator of E.M.F. −98 volts (470/480 of −100) and internal resistance 10kΩ.

The action of the rest of the circuit is such that the potential of the $R_2 - R_1$ junction is kept near to that of the −450 volt line. Hence the circuit of Fig. 1(b) is formed by (R_1 + 10kΩ), R_2 and C_2. It is convenient to choose R_1 and R_2 so that the resistance of (R_1 + 10kΩ) in parallel with R_2 is a round figure, in this case 100kΩ. R_1 and R_2 therefore satisfy the equation:

$$\frac{(R_1 + 10\text{k}\Omega)R_2}{R_1 + R_2 + 10\text{k}\Omega} = 100\text{k}\Omega \quad \ldots\ldots\ldots \quad (4)$$

Then the P.D. between the $R_1 - R_2$ junction and the −450 volt line obeys Equation (2) with $\alpha = 100\ C_2$, where C_2 is in microfarads and α in milliseconds.

An abrupt rise of voltage is obtained by switching C_2 out of circuit by means of switch S. The return of $R_1 - R_2$ junction to the potential of the −450 volt line at the end of the 3-second period is slowed down by C_1, and by C_2 if it is in circuit. This slow return is desirable, as it is usually sufficient to avoid stimulation of the nerve on "break."

The component values shown for the flip-flop give a stimulating current of three seconds duration, provided PB_1 is released in less than three seconds. Other durations could be obtained by choosing C_1 in proportion.

R_3 and C_3 are incorporated to eliminate a small transient which otherwise appears on the output when PB_1 is released.

Servo-stimulator

The P.D. between the $R_1 - R_2$ junction and the −450 volt line is used to control the output current. The valves V_6, V_7, V_8 and V_9 and their associated components operate on the same principle as a circuit given by Rushton[5] and termed by him a "servo-stimulator." V_6 is the actual output valve, and the output current develops a P.D. across R_4, R_5 and R_6 in parallel.

Valves V_7, V_8 and V_9 form a direct-coupled amplifier whose output is applied to V_6 grid, and which operates to keep $R_2 - R_4$ junction near to the −450 volt line potential. Thus the output current is controlled to be proportional to the P.D. between the $R_1 - R_2$ junction and the −450 volt line.

For a given set of values for R_1, R_2 and R_4, the output current I_0 is proportional to the conductance of R_4, R_5 and R_6 in parallel. The decade current setting switches determine the values of R_5 and R_6, as shown in Fig. 4(a).

The current I_0 is made to correspond to 75 volts across R_4, R_5 and R_6. It is convenient to arrange that for $R_5 = R_6$ = infinity, the current through R_4 is the lowest current setting required, namely 0·1mA. Hence the value 750kΩ has been chosen for R_4.

The condition that the P.D. across R_4, R_5 and R_6 should be 75 volts when the output current reaches its final value I_0 necessitates the following relationship among the resistance values:—

$$\frac{R_1 + R_2 + 10\text{k}\Omega}{R_4} = 98/75 \quad \ldots\ldots\ldots \quad (5)$$

Having chosen R_4 = 750kΩ, (5) becomes:

$$R_1 + R_2 = 970\text{k}\Omega \quad \ldots\ldots\ldots \quad (6)$$

Solving Equations (4) and (6) gives R_1 = 103kΩ and R_2 = 867kΩ as one solution. These values have been used.

The figure 98 in Equation (5) assumes that the stabilized negative voltage is exactly −100 volts. In general, the voltage will not be exact. The circuit has been designed assuming a voltage of 100, and when a stabilizer with a slightly different voltage drop is used, the output current under all conditions is changed in proportion. Since the accommodation curve depends on current ratios, it is unaffected.

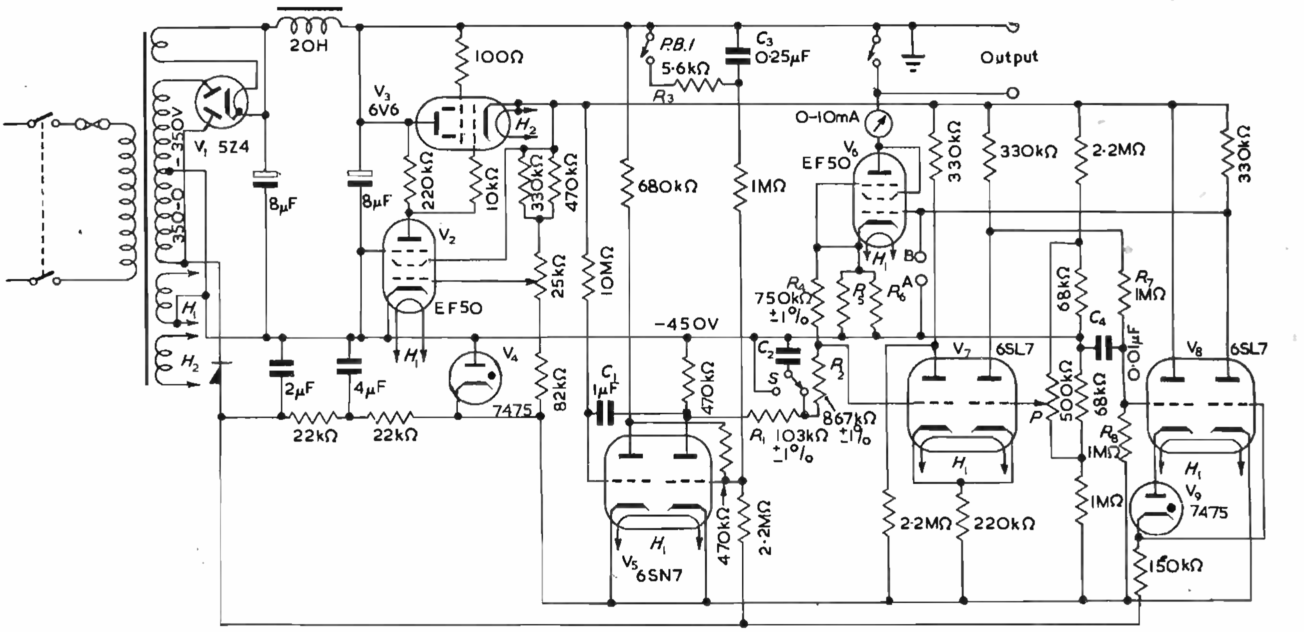


Fig. 3. The complete stimulator

The potentiometer P provides a zero adjustment for the servo-amplifier. It is adjusted to give zero voltage across AB when the output terminals are open-circuited, and the flip-flop is in its stable (" flopped ") condition. With this adjustment, the undesired output current of the stimulator (on short circuit), when not operated, is about 1 per cent of the output current when operated, for all settings of output current.

The capacitor C_4 is needed to prevent H.F. oscillation. It reduces the H.F. response of the servo-amplifier, but its effect on the output waveform is negligible. The time-constant of C_4 with R_7 and R_8 in parallel is 5msec. It can be shown that if the reference voltage at $R_1 - R_2$ junction changes abruptly (as when C_2 is out of circuit) the change in output current is an exponential whose time-constant is 5msec divided by the loop gain of the servo circuit, plus one.

The loop gain, measured between V_7 grid and $R_2 - R_4$ junction, after removing the connexion between these points, is about 200, for all settings of R_5 and R_6, and with the output terminals either short-circuited or connected to resistance loads. Hence the time-constant of the change in output current following an abrupt change in reference voltage is only 25 microseconds.

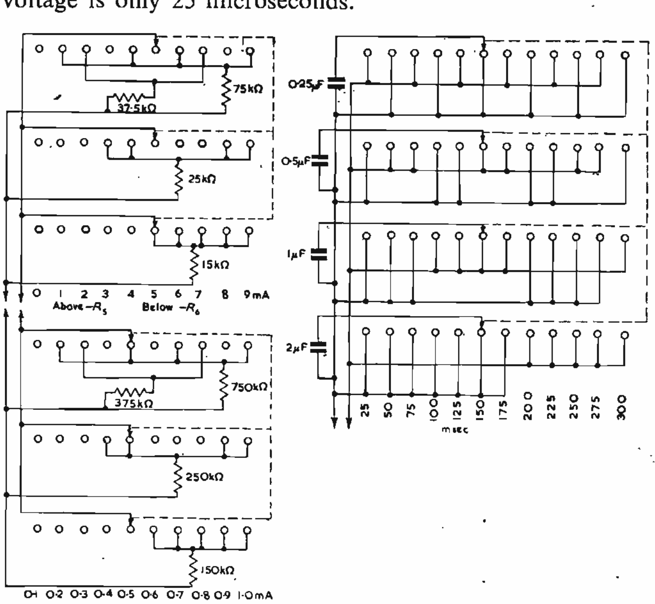


Fig. 4(a) (left). Current setting decades
Fig. 4(b) (right). Time-constant control C_2

The high output impedance of the stimulator has been mentioned. For all settings of output current, the difference between the current through a resistance load, and the current on short-circuit, cannot be detected on a meter unless the load resistance is so high that the voltage developed is in excess of 300 volts.

Circuit Details

The output current depends on the values of R_5 and R_6, which are selected by switches, as shown in Fig. 4(a). The output current is proportional to the sum of the conductances of R_4, R_5 and R_6, a current of 1mA corresponding to a resistance of 75kΩ or a conductance of 13·3 micro-mhos. R_5 gives multiples of 13·3 micro-mhos, and R_6 multiples of 1·33 micro-mhos.

The value of C_2 is selected as shown in Fig. 4(b), giving various time-constants. It is highly desirable to short-circuit the capacitors not in use, to ensure they are discharged when brought into use, otherwise a spurious output current may be obtained when altering the time-constant setting. For a similar reason, switch S is made to short-circuit C_2 when not in use.

The internal screens of the EF50 valves are connected to the −450 volt line, not to earth.

A meter is provided to monitor the output current. After operating the stimulator, the current should be allowed to fall to zero before the setting of output current is altered.

A push button switch is connected across the output. This is regarded as a safety device, to remove the current from the subject should an unpleasantly high current be applied by mistake or through a fault in the stimulator. The button is also useful for testing the stimulator before commencing tests on a subject.

Possible Improvements

A control of the duration of stimulating current would be advantageous. This could be achieved by varying C_2, perhaps having this control ganged with the time-constant control. For the present stimulator, 3 seconds was chosen as being long compared with the longest available time-constant, but when making measurements with shorter time-constants, the need to wait for over 3 seconds between tests makes the process unnecessarily tedious.

Acknowledgments

The author is indebted to the Physiology Department of Glasgow University for the facilities to develop the stimulator, to Dr. S. Renfrew for informing him of the need for such a stimulator and for much other assistance, and to Dr. T. D. M. Roberts for drawing his attention to Reference 5 in this connexion.

REFERENCES

1. BERNHARD, C. G. GRANIT, R. AND SKOGLUND, C. R. The breakdown of accommodation—nerve as a model sense organ. *J. Neurophysiology. 5*, 55 (1942).
2. HILL, A. V. Excitation and accommodation in nerve. *Proc. R.Soc.* series B, *119*, 305 (1935-6).
3. KUGELBERG, E. Accommodation in human nerves. *Acta Physiologica Scandinavica. 8*, Supplement XXIV (1944).
4. KUGELBERG, E. AND SKOGLUND, C. R. Responses of single human motor units to electrical stimulation. *J. Neurophysiology. 9*, 391 (1946).
5. RUSHTON, W. A. H. A servo-stimulator. *J. Physiology.* 108,1P (1949).
6. SKOGLUND, C. R. The response to linearly increasing currents in mammalian motor and sensory nerves. *Acta Physiologica Scandinavica. 4*, supplement XII (1942).
7. SOLANDT, D. Y. The measurement of accommodation in nerve. *Proc. Roy. Soc.* series B, *119*, 355 (1935-36).
8. WIGTON, R. S. AND BRINK, F. Studies of accommodation of nerve in parathyroid deficiency. *J. Clinical Investigation. 23*, 898 (1944).

The Royal Society Conversazione

INCLUDED in a number of interesting exhibits shown at the the recent Conversazione of the Royal Society was a demonstration by Messrs. R. A. Baily and C. M. Burrell, of the Ministry of Supply, of the mechanical effect of microwave power circulating in a high Q-factor cavity resonator.

A metal rod, suspended in the field of an H_{011} cavity resonator operating at 10cm wavelength, was made to deflect by the application of about ½ watt of power at the resonant frequency of the cavity. Because of the high ratio of circulating power to applied power, a reasonably robust suspension may be used. Since the cavity Q-factor may be measured to about 1 per cent, it may be possible to develop a simple form of power measurement for power of the order of milliwatts.

The method is an extension of the recent work of Dr. A. L. Cullen of University College, London, on the mechanical effect of power in waveguides and he has been associated with this work.

Also shown was the original printing telegraph invented by Charles Wheatstone, F.R.S.

This instrument, discovered only last year in a laboratory at King's College, London, was made by Charles Wheatstone in 1841 and is unquestionably one of the first pair of printing telegraphs ever devised.

Although it had been known that Wheatstone patented a printing telegraph in 1841 (i.e. only four years after the invention of the earliest Cooke and Wheatstone electric telegraphs), the existence of an actual instrument remained unknown until a few months ago when the two original instruments were recognized and identified at King's College.

These instruments were never used commercially. In 1841 even the needle telegraph was a novelty, the need for which was scarcely recognized; the world was certainly not ready for a printing telegraph.

The Prediction of Audio-Frequency Response

No. 4—Step Circuits

By N. H. Crowhurst, A.M.I.E.E.

THERE are two possible methods of treating circuits using a single reactance to produce a step in the amplitude response:

(a) They may be resolved as the combination of two equivalent responses of the single reactance cut-off type, one of which is inverted;

(b) the circuit may be treated directly as an entity.

Method (a) has an advantage only where the inverted component coincides exactly in frequency with a normal single reactance cut-off elsewhere in the chain, so the two of identical frequency neutralize, leaving the normal component of the step circuit as the resultant response. For all other cases, treatment as a completely separate circuit gives the best possibility of accurate computation, as well as the most direct approach.

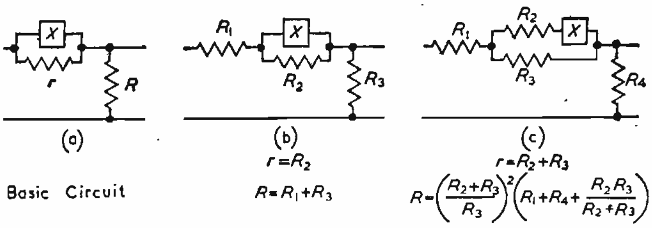


Fig. 1. Basic and practical forms of step circuit with series modifier reactance.

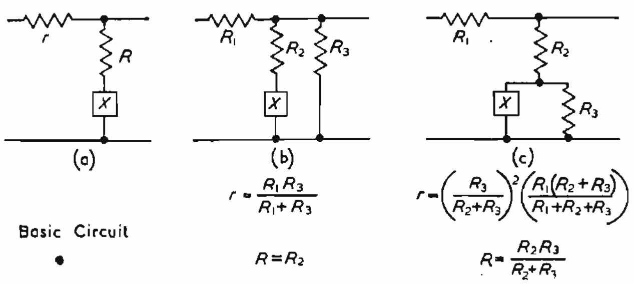


Fig. 2. Basic and practical forms of step circuit with shunt modifier reactance.

Figs. 1 and 2 show the two possible forms of step circuit. In each (a) is the basic circuit, while (b) and (c) are possible practical forms of the circuit, each being reducible to the equivalent shown at (a), by means of the formulæ given. The component marked X may be reactance due to either pure inductance or pure capacitance. Practical capacitors satisfy this specification, but inductors invariably introduce loss components, which may be represented as part of one or more of the resistors in the circuit configuration.

The arrangements shown at (b) in Figs. 1 and 2 are comparatively simple derivations from the basic (a) forms, in a manner directly similar to that shown in Figs. 1 to 4 of the first data sheet in this series (published in November 1951 issue). The arrangements shown at (c) involve more complicated reduction to the basic form, the resistors R_2 and R_3 causing a "resistance transformer" effect for one of the equivalent elements. This may be explained by regarding R_2 and R_3 as a potentiometer in each case: in Fig. 1, R_1 is connected to the "slider", so that with R_2 zero the circuit is of exactly the same configuration as that at (b), while with R_3 zero, X is ineffective, and R_1 and R_4 become a simple attenuator; in Fig. 2, X is connected to the "slider", so that with R_2 zero the circuit is no longer a step, but a single reactance cut-off (as at Fig. 3 of No. 1 in this series), and with R_3 zero the circuit is a simple attenuator; intermediately, in each case, the effect of X is varied by "moving the slider".

In the arrangements of Fig. 1, a capacitance produces a response with the top of the step at the high frequency end, introducing phase advance or lead; and inductance produces a response with the top of the step at the low frequency end, and introduces phase delay or lag. In the circuits of Fig. 2, the direction of step and phase-angle are reversed for the respective reactances.

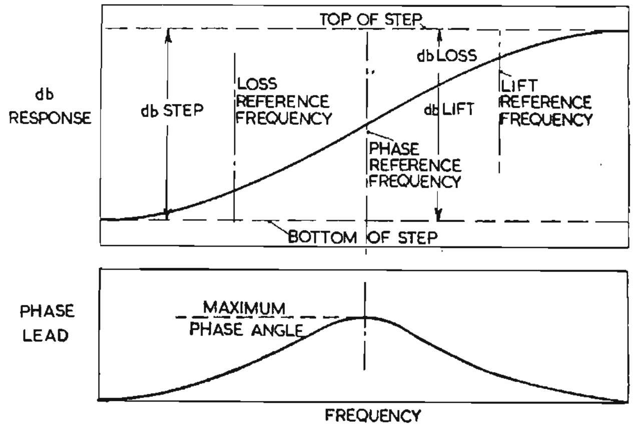


Fig. 3. Amplitude and phase response of typical step circuit, showing reference frequencies and associated db references.

With predictions for these circuits, three reference frequencies, two for amplitude response and one for phase, allow the use of universal curves in the chart design. Fig. 3 shows a typical response, in db and phase, for a circuit of Fig. 1 type using capacitance, or one of Fig. 2 type using inductance. The two reference frequencies for amplitude are symmetrically placed at approximate "turnover" points, at the top and bottom of the step. The reference frequency for phase is midway between these two (using logarithmic frequency scale) at the midpoint of the step, where the phase lead (or lag for steps in the other direction), is a maximum.

There are also two levels from which the db response may be referred—the ultimate top and bottom of the step. The combinations used are: the reference frequency nearest the top of the step with db referred to the bottom level, called the lift reference; and the reference frequency nearest the bottom of the step with db referred to the top

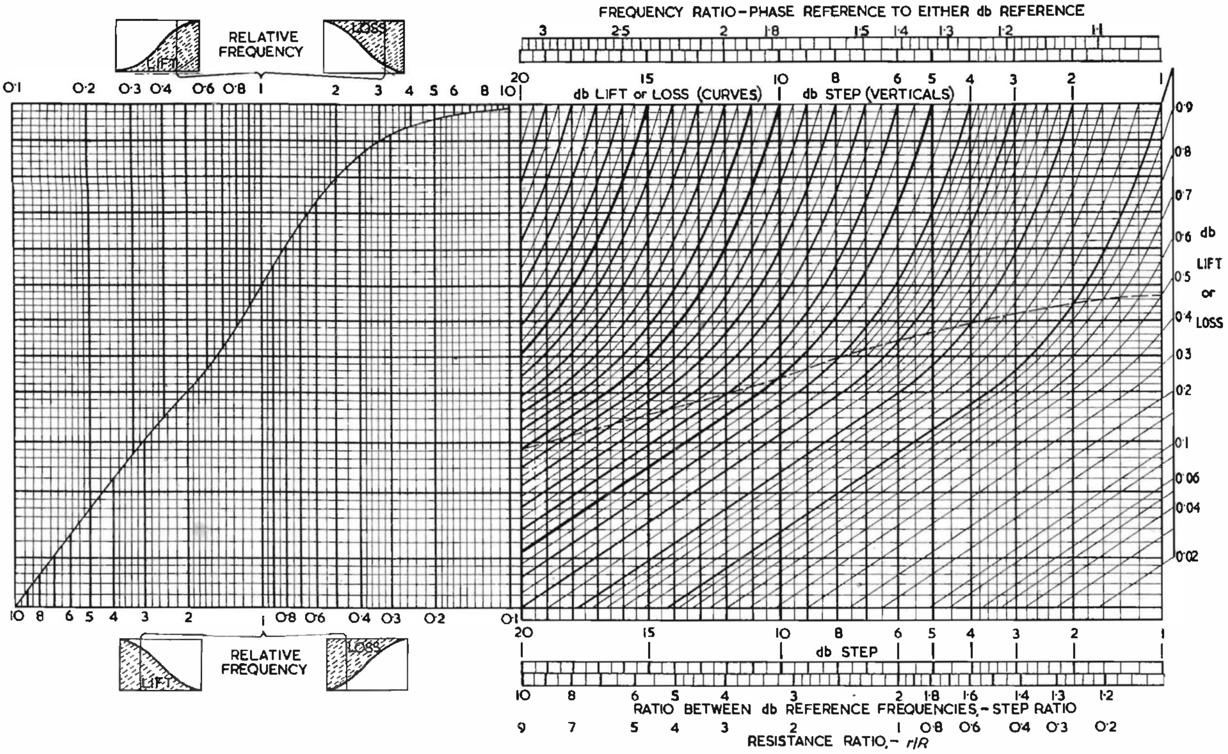


Chart 1. Amplitude response.

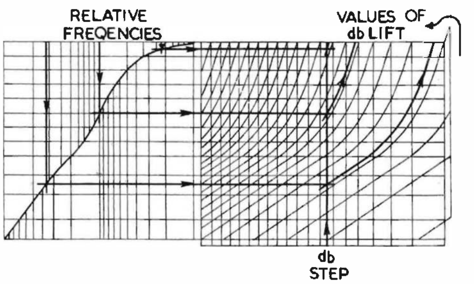


Fig. 4. Illustrating the use of Chart 1.

Chart 2. Phase response.

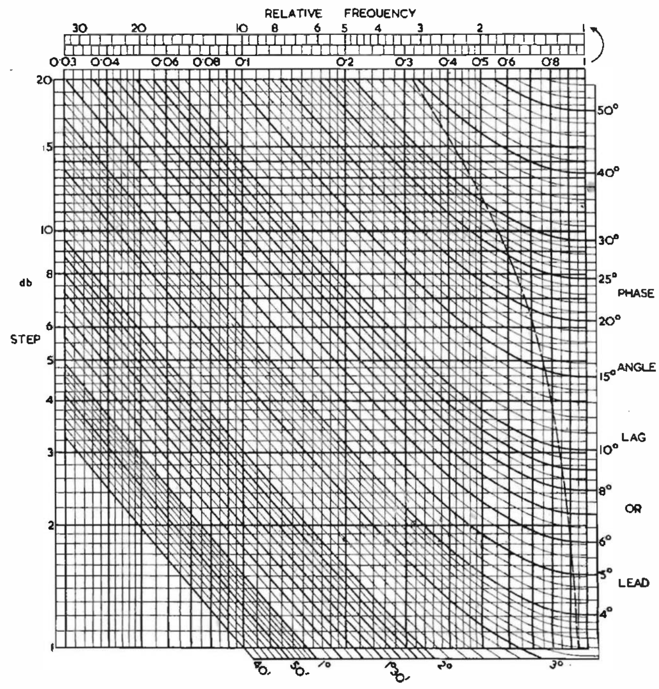
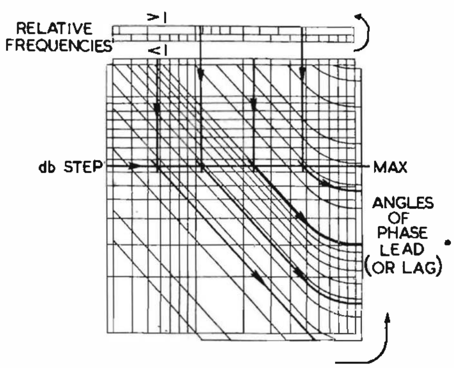


Fig. 5. Illustrating the use of Chart 2.



of the step, called the loss reference. These combinations are used for the charts in this article.

Using these reference frequencies, the universal formula for amplitude response is, writing $a = r/R$,

$$\text{db} = 10 \log_{10} \left[1 + (2a + a^2) \frac{x^2}{1 + x^2} \right] \quad \ldots\ldots\ldots\ (1)$$

Using the lift reference frequency in the circuit of Fig. 1,

$$x = X/r \quad \ldots\ldots\ldots\ (2)$$

or in the circuit of Fig. 2,

$$x = R/X \quad \ldots\ldots\ldots\ (3)$$

Using instead the loss reference frequency, in the circuit of Fig. 1, requires,

$$x = \frac{rR}{X(r + R)} \quad \ldots\ldots\ldots\ (4)$$

or for the circuit of Fig. 2,

$$x = \frac{X}{r + R} \quad \ldots\ldots\ldots\ (5)$$

Otherwise stated:

The lift reference frequency is that at which the value of the reactance is equal to that of the resistance with which it is directly associated, r in Fig. 1, or R in Fig. 2.

The loss reference frequency is that at which the value of the reactance is equal to the ultimate combined resistance: the parallel combination of r and R in Fig. 1; the series combination of r and R in Fig. 2.

The phase reference frequency is the mean of the two amplitude references, and using $y = f/f\phi$, the response is given by,

$$\phi_t = \tan^{-1} \frac{y}{1 + y^2} \cdot \frac{a}{\sqrt{(1 + a)}} \quad \ldots\ldots\ (6)$$

the sign being according to the direction of step.

Use of Charts

Fig. 4 shows how Chart 1 is used to obtain the amplitude response. The small figures alongside the words RELATIVE FREQUENCY on the Chart itself, above and below, provide the simplest identification of the scale to be used for either direction of step given to either amplitude reference. Suppose a lift in the higher frequencies is required; the top left-hand figure indicates that the top frequency scale is the one to use. With this the chart may be used to plot the amplitude response from one-tenth to ten times the upper reference frequency. To obtain the db response at any frequency, the vertical line corresponding to the required db STEP value is used to transfer the readings on the horizontal reference rulings from the left-hand side of the Chart to the db LIFT or LOSS rulings on the right-hand part (the sloping, curved, lines).

As a help in obtaining the correct reference frequencies, and calculating the db STEP value, the auxiliary scales on Chart 1 are provided. Only one frequency need be calculated from the resistance and inductance or capacitance values. The lowest scale of all on Chart 1 can be used to give db STEP directly from the resistance ratio, r/R. The ratio between the two amplitude reference frequencies is simply one plus this resistance ratio, so two sets of numerals are given for the same scale. Normally the lift reference is the simpler to calculate, so evaluation of the other is a simple slide-rule operation using the value from the upper set of numerals to this bottom scale. The scale at the top enables the phase reference frequency to be calculated (by means of a slide-rule) from either of the amplitude references. The dotted curve on the Chart gives the db response at mid-step, i.e. the phase reference frequency.

Fig. 5 shows how Chart 2 is used to obtain the phase response. The angle starts from zero at a low frequency rising to a maximum at mid-step, and falling again to zero at a high frequency as shown in the lower part of Fig. 3. On the Chart, the right-hand edge represents mid-step frequency (the phase reference), and the scales along the top relative frequency symmetrically about this reference. The appropriate db STEP ruling is used to transfer from the vertical frequency rulings to the sloping (curved) phase rulings. The dotted curve on this chart gives the phase-angle at the amplitude reference frequencies.

The amplitude reference frequencies have been described as at "turnover" points: this should not be construed to mean that these points are 3db from the ultimate levels, or of half the maximum slope; both these definitions become approximately true for steps of 20db or more—steps greater than 20db are not shown on the charts, because they can quite readily and accurately be computed as the combination of two responses (method (a) of the first paragraph)—but for steps of less than 10db these definitions are far from true; in fact the slope is almost constant between the two reference frequencies, its value depending upon the depth of step. Note, for example, that the phase shift for a db STEP of 9·5 only varies between 26.5° and 30° between the amplitude reference frequencies, a frequency ratio of 3:1.

Example

Using the arrangement of Fig. 2, with a suitable capacitor, r and R have values of 22kΩ and 10kΩ respectively; the circuit is to give a lift of 3db at 200c/s.

From the scale at the bottom of Chart 1, r/R of 2·2 gives a step of 10db. To find the 3db lift point, the simplest method, using the lift reference, requires the bottom frequency scale; the intersection of the 10db STEP line with the 3db curve leads, along the horizontal rulings, to 2·8 as relative frequency reading, so the lift reference is 200/2·8 = 71·5c/s (by slide-rule); the phase reference is 71·5c/s × 1·775 (from scale at top of Chart 1) = 127c/s; now using the charts with a slide-rule to convert actual frequencies to the relative frequencies used for reference, the following values are tabulated, from which complete curves can be plotted. The lift reference of 71·5c/s is used for amplitude.

FREQUENCY	20	30	40	60	80	100
AMPLITUDE—RELATIVE FREQUENCY	·28	·42	·56	·84	1·12	1·4
db LIFT	9·7	9·3	8·9	7·9	6·9	6·05
PHASE—RELATIVE FREQUENCY	·158	·236	3·15	·472	·63	7·85
PHASE-ANGLE	10·6°	15·3°	19·2°	25·2°	28·5°	30·6°

FREQUENCY	150	200	300	400	600
AMPLITUDE—RELATIVE FREQUENCY	2·1	2·8	4·2	5·6	8·4
db LIFT	4·1	3	1·65	1·05	·53
PHASE—RELATIVE FREQUENCY	1·18	1·58	2·36	3·15	4·72
PHASE-ANGLE	31°	28·6°	23·8°	19·3°	14°

To calculate the value of capacitor required: its reactance must be 10kΩ at 71·5c/s; by standard calculation this is $2{\cdot}2 \times 10^{-7}$F, or 0·22μF.

From the foregoing example it will be seen that quite accurate prediction is possible. Usually the circuit components will be subject to considerable tolerances, so that the accuracy available is very rarely necessary. However, in such cases it is still useful for plotting a good curve, since undue deviation of individual points would produce an irregular shape. As well as providing for precision circuit adjustment, the available accuracy enables the effect of circuit tolerances to be examined.

BOOK REVIEWS

The Magnetron

By R. Latham, M.A., Ph.D., A. H. King, M.A. and L. Rushforth, M.B.E., B.Sc., M.I.E.E. 142 pages. 82 figs. Chapman and Hall, Ltd. February, 1952. Price 18s.

IN this first British book devoted to the subject of modern magnetron oscillators the authors have succeeded in dealing with a most complicated subject on a plane which will enable those who until now have only been concerned with magnetrons as useful sources of centimetre-wave power to understand something of their mode of operation and the problems which confront the specialist in this subject.

The first chapter, together with part of the last, dealing as they do with purely radar matters such as the need for short wavelengths and the split beam technique of direction finding might well have been omitted in a book of this size.

Chapter 2 serves to set the modern magnetron in its right perspective among its competitors of 1939.

The circuit properties of the anode block are dealt with rather more superficially than the mode of operation from the electronic point of view and while it is, no doubt, difficult to deal with these two aspects separately and fully, there are several occasions when what are really properties of the block alone are considered in chapters supposedly dealing with electronics. Two such cases concern conditions. The Hartree harmonics of the R.F. field in the interaction space and the effect of dissimilarity between individual resonators on the splitting of the degenerate non-π modes.

These difficulties might have been avoided if the unstrapped anode had been considered as a waveguide of unusual cross section which could be shown, without resort to too much mathematics, to be capable of propagating a number of different T.E. modes whose relative amplitudes are determined by the boundary conditions. The Hartree harmonics follow simply from this treatment as does the small dependence of the resonant frequency on anode length.

Strapping is well explained by the lumped circuit method used by the authors, but here again the use of the waveguide analogue for the unstrapped block would demonstrate the difficulty of strapping an anode whose length is comparable with the operating wavelength.

Also in connexion with strapping, despite the statement on page 31, it must be pointed out that a considerable number of unstrapped magnetrons were used in the early centimetre wave radar sets.

The circuit properties of the output coupling and the inter-relation of the various Q's with frequency pulling has been well dealt with, but a more detailed description of waveguide output systems, which are almost universal in magnetrons operating below 10cm wavelength, would have been welcome.

The early electronic theory leading up to the derivation of the threshold voltages and maximum electronic efficiency provide a simple and accurate treatment of this invaluable work of Hartree and Banemann, and the same can be said of the authors' exposition of the even more complex instability criterion.

Attempts to derive from this the current at which mode changing occurs have wisely been omitted as experimental correlation is somewhat doubtful.

This book, which is very well illustrated, ends with a good description of most of the manufacturing techniques used in production and methods of performance testing, but noticeable by their omission are the newer glass to metal seals involving alloys of the same expansion as glass and the importance of a measurement of the emitted radio frequency spectrum.

The bibliography will be found most useful by all classes of readers.

H. A. H. BOOT

Materials Technology for Electron Tubes

By Walter H. Kohl. 493 pp. Reinhold Publishing Co., New York. Chapman and Hall, Ltd., London. 1951. Price 80s.

THIS book will be used by all workers in the electronic tube industry, whether in research, development or production, and it should also be useful to research workers in related fields. It is a long-awaited successor—in English—to Espe and Knoll's classic work.

Wisely, no attempt has been made to deal with the many machines in use in the industry, and the book does not include subjects which have been covered fully elsewhere—luminescence of solids, for example, and the treatment of gases and vapours. High vacuum technique, electron emission and gettering are not treated at length although full bibliographies are given. The author has deliberately narrowed his field in this way in order to concentrate on those sections of his subject on which the current literature is inadequate or scattered.

A few salient features of the book deserve special mention. The treatment of glass in the first six chapters, for instance, is excellent, its value to the British reader being greatly enhanced by the fact that both British and American glasses are considered in detail. In particular, the chapter on the analysis of strain in glass gives the most concise and informative summary of the subject this reviewer has yet encountered.

Each of the important valve-making metals is dealt with thoroughly at chapter length, and much valuable metallurgical data is included in the form of tables or of extracts—sometimes lengthy—from other publications. The chapter on nickel is especially good, including, as it does, a summary of the recent work of the American Society for Testing Materials. Zirconium, however, receives little attention and a more extensive treatment of this metal would improve further editions of the book.

Chapters on carbon, on ceramics and on brazing and soldering should be of great interest to workers in these fields. Like the rest of the book they include much information gathered together in one place for the first time and should save much of the time that has previously been wasted in consulting numerous references. But for those wishing to delve further into the subject there are bibliographies attached to each chapter which are so full and up-to-date that they might well serve as a model to all authors.

This is not primarily a teaching book—although it might well serve as a background to the usual lecture courses provided in industry for engineers and scientists. It is a work of reference to which any worker in the valve-making and related industries can turn, confident that he will find useful information. The author must be congratulated on his achievement. The electronic tube industry will certainly make good use of it.

J. D. STEPHENSON

Theory and Design of Valve Oscillators

By H. A. Thomas, D.Sc., M.I.E.E. Vol. VII of a Series of Monographs on Electrical Engineering. 2nd Edition, revised. 317 pages, 157 figs. Chapman and Hall, Ltd. 1951. Price 36s.

IN the preface it is stated that the object of this book is to present valve oscillators in a form suitable for the advanced student and technician; this has been well achieved. The author has dealt effectively with some of the less familiar aspects of valve oscillators in addition to the fundamental theory to be found in standard textbooks on radio engineering.

In Chapter I, the various types of valve oscillators are classified in a useful manner and some of the common *LC* circuits are introduced.

Chapter II, on the conditions for maintaining oscillation, is disappointing in so far that interesting graphs are shown but little information is given on their construction. In particular Figs. 13, 14 and 15 are worthy of more detailed treatment (there is a slight typographical error in Fig. 15) and the explanation on page 29 of the use of the graphs for determining conditions for frequency stability is not at all clear. On page 32, Equation 12 apparently shows that the negative anode slope resistance of a dynatron oscillator does influence the frequency of oscillation, whereas the last sentence in the section contradicts this result without any immediate explanation; the matter is cleared up in Chapter IV, but there is no cross reference for guidance. In spite of these short-comings there is much that is useful and interesting, particularly the derivation of the Hartley oscillator.

The next chapter on amplitude, waveform and efficiency starts off with an erroneous derivation of Class B efficiency, although the correct answer is provided; thereafter the theory of oscillation and the waveform of the oscillatory current is treated in a very satisfactory manner.

The real value of this book is to be found in the following three chapters of some 142 pages, in which the frequency, the frequency stability and the frequency stabilization of LC oscillators is examined from all aspects. In particular, the treatment of the dependence of frequency on harmonics, the effect of valve interelectrode capacitance and inductor resistance is most satisfying. Useful practical information is given in great detail enabling the student to assess the important factors of oscillator design without difficulty. There are tables of the relevant characteristics of various materials used in the construction of oscillator circuits, and diagrams showing the general assembly details of temperature compensated components. In these chapters, the reader enjoys the benefit of the author's wide experimental experience.

The next two chapters on RC and crystal oscillators are very short and, as stated in the preface to this edition (the second), have been added for completeness.

Ultra-high-frequency oscillators are the subject of Chapter 9, which is mainly descriptive and very short. There are some good diagrams of coaxial line oscillators, but the treatment is too brief to be satisfying. Table 13, on page 241 is included with no explanation of its origin, and on the same page frequency is quoted in megacycles/sec. but in the formulæ for Q of transmission lines it is obviously meant to be in cycles/sec.

In Fig. 110 (page 243) showing diagrams of resonant line oscillators no allowance is made for the effect of valve capacitance loading the resonant lines and this point is not mentioned in the text.

The brief description of the reflex oscillator in Chapter 10 is very helpful due mainly to the diagrams used, the anode gap admittance diagram (Fig. 140) being particularly good (although the transit time spiral is incorrectly numbered). The spiral grid valve is mentioned, but its action is not fully explained.

The last chapter (again very short) is devoted to magnetron oscillators. There is a good description of the cavity magnetron and several excellent diagrams.

It is unfortunate that additional space could not have been allowed for the last three chapters which have suffered considerably from compression in comparison with the excellent chapters on LC oscillators.

A bibliography of 172 references completes the volume.

The book is highly recommended for students and engineers who are particularly interested in stable LC oscillators and forms a very valuable contribution to technical literature on this subject. There are no wide gaps in the development of mathematical formulæ which might discourage intermediate students, but the mathematical standard is adequate for the very satisfactory proofs which are employed.

H. V. Sims

Radioisotopes—Industrial Applications

By G. H. Guest, M.A., Ph.D., 185pp., 65 figs. Sir Isaac Pitman and Sons, Ltd. February 1952. Price 35s.

THE production of radioisotopes on a large scale in chain-reacting piles has stimulated the use of these materials in many branches of scientific endeavour, and already they have found many important uses in medicine and research. It seems probable that wide application will be made of this new technique in industry. The present book by Dr. Guest is the first book to be published dealing exclusively with industrial applications.

Dr. Guest was, for a time, in charge of the Isotope Branch of the Atomic Energy Project, National Research Council, Canada, and so he is able to write with authority on these matters. This book includes introductory chapters on the characteristics and production of radioisotopes and the technique of using radioisotopes both as radiation sources and as "tracers" or "indicators", but the greater part of the book deals with the actual applications of the new technique in industry. The subjects of the later chapters are radioisotopes in applied metallurgy and in metallurgical research, in iron and steel production, in friction and lubricating studies, in glass and ceramic research, in the petroleum industry, in the rubber and chemical industries and in hygiene and public health. There are also chapters dealing with the uses of radiation sources for industrial radiography, as well as those devoted to a consideration of the design of laboratories and workshops for radioisotope work and to the special precautions which must be observed in using radioisotopes.

The layman reader will find in this book an interesting and intelligible account of the subject. The examples of the applications cover such a large field that he cannot fail to be amply convinced of the tremendous potentialities of the new tool. The technician and the industrial scientist may, however, find the book disappointing in several ways. Thus, although the book gives numerous examples of the applications of radioisotopes, much of the information required by the *user* of these applications is omitted. Again, the reader will find all the advantages of the new technique properly emphasized, but in some cases the disadvantages are either not mentioned, or their influence is minimized, so much so that one fears that the non-critical reader may obtain too optimistic an impression of the efficacy of the new technique. The subject of instrumentation is mentioned, but there is insufficient information and critical discussion of the various possible types of particle and radiation detector for the reader to make any assessment of the correct type to use for a particular application. Thus in discussing the important subject of the radioactive thickness gauge the author explains the basic principle of the simple gauge and the back scattering type of gauge, but he gives no details of the design of the ionization chamber detector or the associated measuring circuit.

The book is well printed on good quality paper and the illustrations are clear and accurate.

The reviewer's general verdict is that the author has produced an interesting and valuable book for the layman, but in his enthusiasm to cater for the layman, he does not quite meet the needs of the more scientific reader.

Denis Taylor

BOOK REVIEWS (Continued)

Harwell—the First Five Years

182 pp., 32 photographs. Her Majesty's Stationery Office. May, 1952. Price 6s.

THIS book presents an account of British atomic energy research from 1946 to 1951, and is the first official story of the work to be published.

It gives an account of the main research programmes and of the progress that has been achieved in them. An attempt has been made to satisfy the interest of the general reader, and at the same time to summarize for the technician the advances in new fields of research.

The primary object of the research scientists at Harwell is to develop means of obtaining power to provide electricity and to drive ships, and there are indications that this result will be achieved in the comparatively near future. While this main object is being pursued however, by-products of atomic energy have been developed which provide new tools for doctors, agriculturists, industrials and research workers.

After giving a brief résumé of the events leading to the formation of the Atomic Energy Research Establishment in 1946, and a review of its organization, there comes a description of the main tasks on which Harwell is working. These are treated in some detail under four headings: the production programme; isotopes; nuclear reactors, and particle accelerators.

During the first few years Harwell's main task was to supply technical information to the atomic energy production organization centred on Risley, particularly in connexion with the design of the plutonium production piles and chemical separation plant at Sellafield in Cumberland. A general picture of the problems tackled in this field is given, and the need for attention to detail is emphasized.

The book next surveys the methods of producing radioisotopes and their applications. A new use in the medical field is shown in an illustration of a skin graft operation, where the injection of a radioisotope into the graft has enabled surgeons to find out whether the graft has taken, and so to proceed more quickly and with more certainty of success to the next stage of the operation.

An account is given of the development of new types of reactor for the production of useful power. Since reactors are extremely costly, it has been necessary to devote considerable time to studying the possibilities, particularly when the technological resources for building are limited as they are in the United Kingdom. As a result of these studies three types of reactor have been chosen, and it would appear that a building programme is under consideration.

Many new technical problems have to be tackled in the course of a reactor development programme; among those mentioned are the use of new materials, such as beryllium and zirconium, the use of liquid metal coolants for achieving very high heat-transfer rates, and the effects of very intense nuclear radiation on materials.

Two things not widely known emerge from the account. The first is the way in which the British lead in synchrotron and linear accelerator design has sprung from their war-time radar experience—an A.E.R.E. group working at the Telecommunications Research Establishment, Malvern, had the first synchrotron working there in August, 1946, and the first linear accelerator in November of the same year. The second is the use of these accelerators in radiotherapy, and collaboration with the Medical Research Council in choice and design of the most suitable machine is described.

A very important part of the subsidiary programme at Harwell is the service given by the Medical and Health Physics Divisions. To ensure that no-one shall be exposed to harmful amounts of radioactive or toxic materials is a major task, and the way in which the problems have been successfully overcome is described in detail.

Some of the fundamental research at Harwell in the fields of physics, chemistry and metallurgy is described. While the physics research is principally concerned with the investigation of the nucleus, a great deal of study is also given to the effects of irradiation, particularly pile irradiation on aggregates of atoms. Much of the pure research in chemistry has been directed towards the study of the heavy elements and the artificially created transuranic elements. The book deals with various investigations which have taken place, particularly into the electron configurations of the transuranic elements. The work done in radiation chemistry at Harwell is also described.

Many of the researches undertaken in metallurgy are of fundamental interest in metal physics, such as the study of the crystal structure of uranium, which is orthorhombic in form at room temperature. Uranium alloy systems, powder metallurgy and the examination of metals under polarized light are three of the other subjects reviewed in this section.

Finally, Harwell's collaboration with other research organizations is described. Lectures, training courses at the Harwell Isotopes School, symposia and conferences are mentioned. The first appendix lists nearly 300 papers by members of the staff, published in scientific journals, and the second appendix gives details of the two Harwell piles, Gleep and Bepo. Reading lists in atomic energy are also provided.

To sum up, the account should prove interesting reading to anyone acquainted in broad outline with present theories about the structure of the atom and the nucleus, and the fundamental particles of matter, who wishes to learn more about the work carried out at the Atomic Energy Research Establishment. The book is well illustrated by instructive photographs and drawings.

PUBLICATIONS RECEIVED

THE SCIENTIFIC EDUCATION OF PHYSICISTS has been published by the Institute of Physics as a guide to boys and girls who contemplate physics as a career, and to their parents and teachers. The report includes factual information on the physics departments of all the universities and university colleges of the United Kingdom, and of those technical colleges which are recognized by the Institute of Physics. The nature of the honours course in physics in each university is indicated, together with the approximate number of students admitted each year. Th main branches of physical research now in progress are also given. Copies of this report are obtainable from the Institute of Physics, 47 Belgrave Square, London, S.W.1., price 2s., post free.

THE B.B.C. TYPE "B" DISC RECORDING FEEDBACK CUTTERHEAD AND THE GRAMPIAN RECORDING AMPLIFIERS is a booklet produced by Grampian Reproducers, Ltd. It includes circuit diagrams, tables and data of the Cutterhead and details of the Grampian R.A.3a Amplifier. Copies are available from Grampian Reproducers, Ltd., Grampian Works, Hanworth Trading Estate, Feltham, Middx., price 5s.

B.I.C.C. CAPACITORS FOR RADIO, TELEVISION AND ELECTRONIC EQUIPMENT is a catalogue dealing with paper-dielectric capacitors. It is attractively produced, with the data tabulated, and the capacitors are illustrated. British Insulated Callender's Cables, Ltd., Norfolk House, Norfolk Street, London, W.C.2.

DUBILIER INTERFERENCE SUPPRESSOR CAPACITORS is a six-page leaflet dealing with the various types of suppressors available from this firm. The pamphlet is obtainable from the Dubilier Condenser Co. (1925), Ltd., Ducon Works, Victoria Road, North Acton, London, W.3.

RESISTANCE WIRES AND TAPES. MOLYBDENUM RODS, WIRES AND TAPES. This booklet describes the principal products of Vactite Wire Co., Ltd., and has been compiled with a view to assisting designers of apparatus in which these products may be employed. Vactite Wire Co., Ltd., 24 Queen Anne's Gate, London, S.W.1.

REDIFFUSION BY BROADCAST RELAY SERVICE, LTD., is a profusely illustrated booklet explaining in non-technical terms the system of receiving sound and television broadcast programmes by wire. Broadcast Relay Service, Ltd., Carlton House, Lower Regent Street, London, S.W.1.

GAS AND ELECTRIC FURNACES deals with the complete range of Birlec's furnaces, including gas and electric heat fired treatment types, and arc and induction melting types. Mention is also made of induction heating equipment for both forging and heat treatment applications,' Birlec Lectrodryers for drying compressed air, process gases, etc., and Birlec melting furnaces. Copies of this brochure may be obtained free from Birlec, Ltd., Tyburn Road, Erdington, Birmingham, 24.

ENGLISH ELECTRIC "C" TYPE CORES FOR HERMETICALLY SEALED AND OPEN TYPE TRANSFORMERS AND CHOKES is a new leaflet giving details in tables and data sheets of the types available. The English E'ectric Co., Ltd., Transformer Sales Dept., East Lancashire Road, Liverpool, 10.

DOWN WITH INTERFERENCE is a booklet which is being distributed to radio and electrical dealers and servicemen throughout the country as a guide to the best way of suppressing interference with radio and television receivers, but it is not available to the general public. The booklet has been prepared and issued by the Radio and Electronic Component Manufacturers Federation, 22, Surrey Street, Strand, London, W.C.2., in cooperation with the Radio Industry Council. It contains a list of suppression circuits with recommendations for their use, and has been amusingly illustrated by Ffolkes.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

The Design of Series-Parallel Voltage Stabilizers

DEAR SIR,—In this article in the March 1952 issue the impression is given that the author has found the CV345 (12E1) to be admirably suitable as a regulator valve although classed as a power amplifier. In fact, the 12E1 is listed as a beam tetrode for series or shunt control in stabilized power packs, and no information is published as a power amplifier. Indeed, under the title of CV345 the valve was developed specifically for this purpose.

Attention is also drawn to the absence of information on the subject of high frequency instability in voltage stabilizers. This is a serious problem particularly when cascaded amplifiers are used to obtain high performance both with or without load correction resistance. One common method of stabilizing against high frequency oscillation is a small capacitor not exceeding 100pF between anode and grid of V_2. When this is in use the output impedance is inductive in character and the addition of a capacitance across the output may actually increase the output impedance at particular frequencies quite unlike Fig. 4. With quite normal values of output shunt capacitor the resonant peak will move with further increase of capacitance into the audio frequency range even down to one or two kilocycles. Unless the stabilizers are carefully designed instability (H.F.) will occur with some critical values of inductive or capacitive load and such units must be used with caution during the development and testing of circuits fed from such supplies.

The author also fails to mention that the performance of the unit to a sudden change of load or mains voltage is dependent on factors other than the H.F. response of the amplifier. Particularly in the case of choke filtered units, a time delay exists for the build-up of current through the power supply filter circuit with a sudden increase of load, and a high surge voltage is developed across the circuit when the load is suddenly changed from full value to zero. It is quite common for the control circuit to fail to cope with such conditions unless very large smoothing capacitors are fitted and the amplifier circuit is designed to deal with surge voltages quite outside normal supply voltage variations.

Instability in load compensated circuits may also occur when V_3 is replaced as the voltage/current characteristic of these tubes is subject to many variations.

Yours faithfully,

S. N. POCOCK

Special Products Dept., Development Laboratory, The Edison Swan Electric Co., Ltd.

The author replies:

DEAR SIR,—I was interested to read Mr. Pocock's letter concerning my recent article.

With regard to the valve CV345 (12E1) I consulted "Radio Valve Data" (2nd edition 1951) compiled by *Wireless World* for information on its characteristics. Here the valve is listed under the section "Output Valves I". In general, under this heading in the booklet, triodes, beam tetrodes and pentodes are all included, together with normal maximum operating conditions as output valves for Class A operation (A.F. application). An additional note is given regarding maximum values of anode current and voltage for this valve when used in stabilized H.T. supply circuits. This was the reason for stating in the article that the CV345 is classed as a power amplifier in specifications. I thank Mr. Pocock for pointing out that the valve was developed specifically for use as an element in voltage stabilizers.

I have not actually experienced the difficulties caused by high-frequency oscillations in stabilizers which are mentioned by Mr. Pocock. Fig. 4 was plotted for a typical supply unit of the type shown in Fig. 2 but which incorporated several of the other improvements outlined in the article. This unit was not stabilized, however, against high-frequency oscillations.

I agree that the value of the article would have been improved somewhat by including more information on the performance of stabilizers to sudden changes of either load current or mains voltage.

The characteristics of glow-discharge tubes are now thought to be well-known and several references on this subject were given in the article for further reading. If a good high-stability tube is used for V_3 it is unlikely that it will need replacement for an exceedingly long time. Tests I have in progress show that the characteristics of high-stability tubes of the type 85A1 change very little during the first 25,000 hours of life when operated continuously at a current of 5mA. There is nothing to suggest that, after this long time, the useful life of a tube is being approached.

Yours faithfully,

F. A. BENSON,

Department of Electrical Engineering, The University, Sheffield.

Versatile Phase-Angle Meter

DEAR SIR,—The Versatile Phase-Angle Meter described by Dr. Patchett in the May 1952 issue has several interesting features, which make it a valuable instrument for student use, ease of operation and ability to withstand high input signals being the most important.

We have been operating experimentally for some time a phase-angle indicator in connexion with one of our research programmes. In our unit the circular time-base is produced by two sinusoidal signals generated by a simple two pole machine of unusual design. By this means the time-base is maintained circular and by arranging suitable gain control in the associated amplifier, the diameter of the trace is maintained at a useful size over a wide range of speed. These requirements are essential as the unit is used with rotating out-of-balance vibration exciters, and continuous record of the phase difference between out-of-balance force and the vibration produced is obtained without any adjustment of phase-splitting networks or amplifier gain controls with changing frequency.

For photographic recording and general observation, we prefer a dim trace brightened by the signal pulse, but agree that the inverse condition possibly gives a more accurate reading as well as a continuous check on time-base distortion.

In the present unit where the signal frequency may range from 15 to 200c/s a very elementary pulse forming device, employing only two miniature pentodes, has proved quite satisfactory where the sinusoidal input is greater than 2 volts.

The generator and amplifier for producing the time-base are push-pull throughout so that second harmonic distortion may be largely eliminated and a good circle obtained.

In an alternative form of indicator we are proposing to use a pulse to give a radial line, which will be modulated in brilliancy so that the phase-angle of several signals relative to the reference may be identified readily by the frequency or form of brilliancy modulation. The employment of a Von Ardenne type of cathode-ray tube with a conical deflecting electrode would simplify the circuitry for this modification.

It is hoped that details of the complete apparatus and generator will be published in due course.

Yours faithfully,

DOUGLAS S. GORDON,

Dept. of Electrical Engineering, The University, Glasgow, W.2.

The author replies:

DEAR SIR,—I am interested to read of the phase-angle indicator described by Mr. D. S. Gordon in his letter.

The use of a two-phase generator does overcome the need for adjustment with change of frequency, but is limited in its application. The use of a bright trace is considered desirable so that a continuous check on the position of the circle can be made. I also consider it is easier to read accurately a marker which extinguishes the spot rather than increases its brilliance.

At the reduced frequency range used by Mr. Gordon simpler limiters may be used particularly if the input does not vary over a large range, but it is important that the waveform be limited equally in both directions. If limiting occurs more in one direction than the other errors will occur.

I shall be pleased to see details of Mr. Gordon's circuit when published.

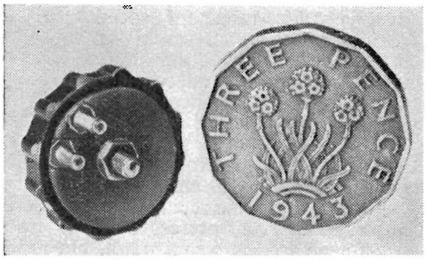
Yours faithfully,

G. N. PATCHETT,

Eccleshill, Bradford, Yorks.

ELECTRONIC EQUIPMENT

A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.



Sub-miniature Potentiometer

(Illustrated above)

EGEN Electric, Ltd., have produced what is believed to be the smallest 3MΩ logarithmic law potentiometer in the world. The track is formed by carbonaceous deposit, and the casing is a plastic moulding. The dimensions are 11/16in. by 3/16in., and the weight is under three grammes.

The potentiometer has been designed for incorporation in a deaf aid, where compactness is essential. It also has the advantage of very low electrical noise.

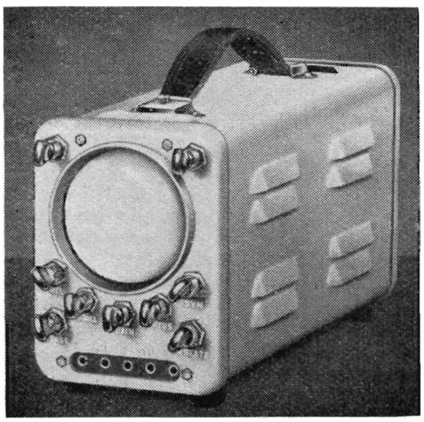
Egen Electric, Ltd., Charfleet Industrial Estate, Canvey Island, Essex.

Cossor Portable Oscillograph

(Shown below)

THE new Cossor portable oscillograph, Model 1039, weighs 9¼lb, and is equipped with a 2¾in. diameter tube which gives a screen size adequate for most monitoring and servicing displays. To safeguard against transit fractures, the nine control knobs of the instrument are in metal, and the tube face is protected by a domed metallic cap fitting into the raised bezel of the front panel. The input connexions of this model are by five recessed sockets giving access to the X and Y plates, amplifier, synchronization and earth.

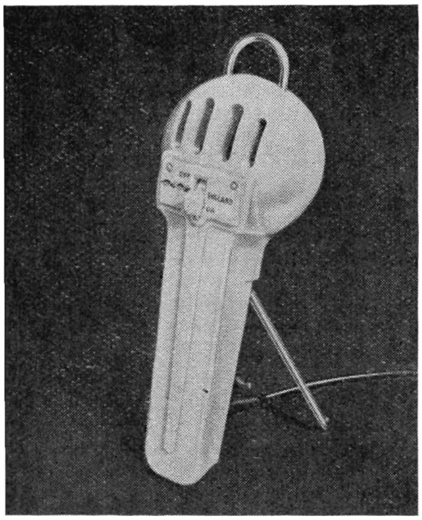
A single-stage amplifier is switched to provide the following facilities: D.C. or A.C. to Y plate; signal to amplifier at high gain and low bandwidth, or signal to amplifier at low gain and high bandwidth. The total frequency is from 25c/s to 3·5Mc/s, the two ranges being 25c/s to 150kc/s (30 per cent down) at a gain of 60, and 25c/s to 3·5Mc/s (30 per cent down) at a gain of 10. Maximum sensitivity of high gain range is better than 0·086 volts/mm with a maximum permissible undistorted amplitude of 4·5cm, while on the low gain range it is better than 0·52 volts/mm with a maximum permissible undistorted amplitude of 1cm. The amplifier has continuously variable gain control.



The free-running hard valve time-base provides symmetric deflexion to the X plates with repetition frequencies of 10c/s to better than 50kc/s in five ranges with a minimum sweep amplitude of not less than 5cm at the highest velocity. Synchronization is by a negative pulse applied to the front panel socket. A switch position disconnects the internal circuits and allows the application of an external time-base.

In the cathode-ray tube the X and Y plates have a sensitivity of 170/V 0·19mm per volt D.C. (5·2V/mm).

A. C. Cossor, Ltd., Cossor House, Highbury Grove, London, N.5.



Combined Hand-Desk Microphone

(Illustrated above)

THE Acos MIC 30 microphone has been designed to function as either a hand or desk model, the conversion being effected by a simple snap action of the spring loaded legs which normally fit into the handle. Provision is also made for suspending the microphone by means of a metal loop which is incorporated in the housing. It is a general purpose crystal microphone having a substantially flat characteristic with a high sensitivity.

The microphone insert is mounted in shock absorbent material which affords ample protection against rough handling. An on-off switch is incorporated, and there is provision for closing an extra circuit. The frequency response is substantially flat from 50-5,000c/s. and the output level is −55db ref 1V/dyne/cm². A load resistance of two megohms is included, and the microphone is supplied with a 4ft length of cable.

Cosmocord, Ltd. Enfield, Middx.

New Germanium Diode GD4

THE Brimar GD4 is a germanium diode which, together with the GD3, were designed specifically for the commercial side of the radio industry.

Produced particularly for noise limiter use in television receivers, where the peak inverse voltage rating is as high as 50 volts, this diode can replace the GD3, should the latter's lower voltage handling capabilities and lower back resistance be inadequate.

The treatment of the germanium surface and the design of the cats-whisker in this new diode make it suitable to stand up to severe mechanical shock. It is sealed in a ceramic tube, and will not deteriorate under changing climatic conditions.

Small in size (about that of a half-watt resistor), the diode can be suspended in the wiring, thus aiding the reduction of stray capacitances. Damage during the soldering of lead wires is practically eliminated by the employment of special wire which, while possessing low electrical resistance, has the advantage of low thermal conductivity.

Comparative characteristics of the GD4 and GD3 are given below:—

CHARACTERISTICS AT 20°C.

TYPE	MAXIMUM FORWARD RESISTANCE AT +1 VOLT	MINIMUM REVERSE RESISTANCE AT −10 VOLTS	MAXIMUM PEAK INVERSE VOLTAGE
	ohms	ohms	volts
GD4	350	250,000	50
GD3	350	50,000	25

Brimar Valves Division, Standard Telephones and Cables, Ltd., Footscray, Sidcup, Kent.

Ferranti Ceramic Valves

AS briefly mention in the May issue on page 249 Ferranti Limited have recently developed certain valves which employ ceramic envelopes in place of the conventional glass construction. This development aims at producing a valve of small dimensions for a given power which implies a high operating temperature, and for which the use of glass is precluded in view of its melting point. Secondary advantages of a ceramic envelope are that it can be subjected to a more stringent processing resulting in rugged construction and, in certain instances, the use of ceramics reduces H.F. losses

The problem involved in the construction of such valves is that of producing a satisfactory ceramic to metal seal which will remain vacuum tight at high temperature. The valves demonstrated at the Physical Society's Exhibition used an iron oxide process which is particularly applicable to low loss magnesium-aluminium silica ceramics.

This process involves the firing onto the ceramic of a film of ferric oxide at high temperature. Reduction in hydrogen is then carried out forming a surface of metallic iron to which metal tubes are brazed. Nickel iron is used as a rule for the tubes as its expansion characteristics are similar to those of the ceramic.

Valves so far developed using this technique are as follows: a planar electrode triode capable of permitting 10 watts anode dissipation (overall height 3·5in. approximately, diameter 0·5in.); a cylindrical electrode triode which provides for 8 watts dissipation (overall height 2·5in. approximately, diameter 0·31in.); and a planar electrode triode of particularly rugged construction having a 5 watts anode dissipation (overall height 2·3in. approximately, diameter 0·31in.).

The inter-electrode capacitances of these types are of the order of 1 to 2pF.

These valves have been developed for operation in the 1,000Mc/s band, and efficiencies of 40 per cent can be achieved. Oscillations can be obtained up to 2,000Mc/s.

The operating temperature of the valves is of the order of 200° C.

Ferranti, Limited,
Ferry Road, Edinburgh.

E.M.I. Mains Suppressor

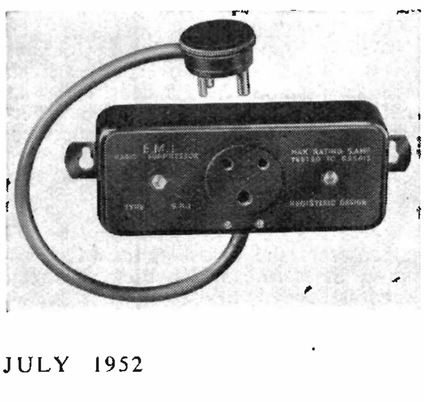
(Shown below)

THE E.M.I. all-wave mains suppressor model S.R.1 has been designed to eliminate interference to radio receivers from nearby domestic and industrial electrical apparatus.

The suppressor consists of a choke-capacitor network, and has a frequency suppression range of 10-2,000 metres which covers all wavebands on domestic radio receivers. It can be used with receivers or appliances operating on either A.C. or D.C. mains, 100-200V and drawing current up to 5A maximum.

The unit is contained in a bakelite case designed for wall or skirting board mounting.

E.M.I. Sales and Service, Ltd.,
Hayes, Middx.



Morgan Megistor

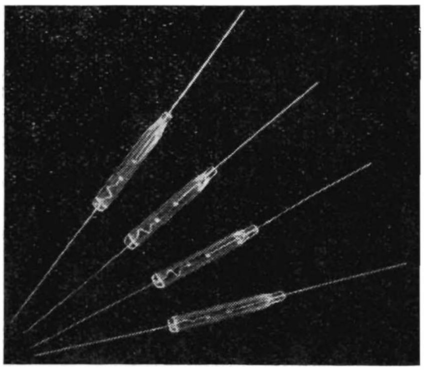
(Shown below)

THE Morgan Megistor is a high value glass enclosed resistor, of high stability covering the range of 10^7 to 10^{13} ohms. It is particularly suitable for use in the very small current circuits of radiation detecting and monitoring equipment. The resistance element is robust, and sealed in an evacuated glass envelope to ensure a high degree of stability. The outside of the glass envelope is coated with a water repellent silicone lacquer.

The maximum overall dimensions of the glass envelope are 1⅞in. long and 7/32in. diameter. The leads are axial, 1½in. to 2in. long, of 24 to 25 S.W.G. wire, tinned to within ½in. of the glass envelope.

Megistors are suitable for working in the range of 0 to 300 volts. The change of resistance with applied voltage is small and reversible, and varies in magnitude with the resistance value. The voltage coefficient is expressed as an average percentage change per volt over the range 1 to 100 volts. The Megistors have a temperature rating of 0 to +60° C. Preliminary tests indicate that the range can probably be extended downwards to −60° C. The nominal resistance value is measured at 25° C. The temperature coefficient is in the following limits: 10^7 to 10^9 ohms, 10^9 to 10^{11} ohms, and 10^{11} to 10^{13} ohms. It is expressed as an average percentage change per °C over the range 0 to 60° C. The self-capacitance is approximately 0·2pF.

The Morgan Crucible Co., Ltd.,
Battersea Church Road,
London, S.W.11.

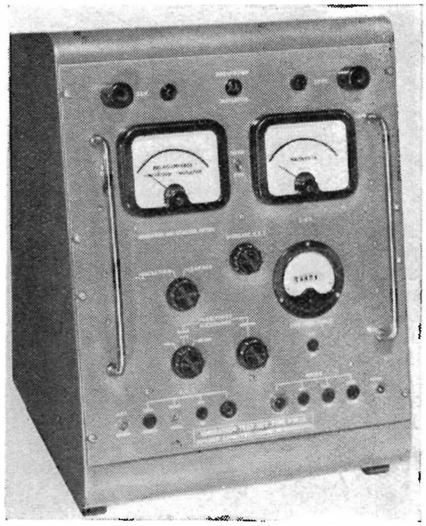


Hivolt Ionization Test Set

(Illustrated top right)

THE Hivolt ionization test set type 105 PMIE enables measurements to be made disclosing any incipient breakdown, so that a component having intense ionization occurring at its working voltage may be measured and rejected prior to installation.

In operation the test set is connected to a component and the voltage applied is then raised to equal the maximum working voltage of the component. In general, no ionization should be tolerated within the working voltage, and in an average sample commencement of intense ionization occurs at approximately one and a half times the working voltage. Quantitative units related to a definite



input voltage are indicated on the ionization meter.

Using a Hivolt R.F. E.H.T. transformer with a tapped tertiary, two separate rectifier circuits are used to supply the 300 volts to 3kV and 3kV to 30kV ranges. The filaments of the rectifiers are heated by R.F. filament transformers of special design, sealed in polythene. Care has been taken in the mechanical design of this unit to avoid the formation of a corona. In the ionization amplifier and meter the earth return from the component or material under test is made via a 75 ohm impedance. The ionizing currents, if present, develop a voltage across this impedance which is amplified in the high gain R.F. amplifier tuned to a selected frequency band representative of the wide range of frequencies over which ionization occurs. Indication of the level of these voltages is given on a linear scale 5in. meter. For the leakage current trip circuit a D.C.-coupled "flip-flop" is used with a relay in the anode of one valve. The D.C. current through the material or component develops a voltage at the grid of the "flip-flop" sufficient to trigger the circuit and operate the relay. Using the fine and coarse controls the circuit will trip between 1 and 250 microamps. The relay operates contacts breaking the H.T. supply to the E.H.T. oscillator and so turns off the E.H.T. The life test timer can be switched on at the start of a life test. On breakdown the clock is automatically stopped as the E.H.T. is switched off. Testing can therefore continue in safety in the absence of the operator.

All filament supplies are controlled by the A.C. mains switch. When the E.H.T. switch is operated, H.T. is applied to the main oscillator making E.H.T. immediately available. E.H.T. variation is obtained by controlling the D.C. conditions on the E.H.T. oscillator. A stabilized mains power pack produces all the supplies for the E.H.T. and the trip units. A D.C. amplifier is incorporated to stabilize the output for changes of mains voltage of +5 and −15 per cent.

Hivolt, Ltd.,
34a Pottery Lane,
London, W.11.

Notes from the Industry

R.I.C. Premiums for Technical Writing. The panel of judges appointed by the Radio Industry Council to award premiums to the authors of articles deserving to be commended by the industry, hopes to make is first awards in respect of articles published between January 1 and June 30, 1952. This will enable the results to be announced and cheques presented at the National Radio Show, which is being held at Earls Court, London from August 26 to September 6.

The announcement and conditions for the award of premiums were published on page 482 of the December 1951 issue of ELECTRONIC ENGINEERING. Full particulars of the competition are available from the Secretary, the R.I.C., 59 Russell Square, London, W.C.1., to whom entries should be sent not later than July 7, 1952.

A Telecommunications Industries Standards Committee has been formed and has held its first meeting at the British Standards Institution. Chairman is Mr. O. W. Humphreys, and represented on the Committee are the Ministry of Supply, Ministry of Civil Aviation, G.P.O., D.S.I.R., British Electricity Authority, B.E.A.M.A., T.E.M.A., and the R.I.C., which is represented by two nominees from each constituent association and the Director, Vice-Admiral J. W. S. Dorling.

Marconi Marine Scholarship Scheme. A scholarship scheme is being instituted by the Marconi International Marine Communication Co., Ltd. in order to provide financial assistance to young men who wish to embark on a career at sea as radio officers.

To inaugurate the scheme it has been decided to award fifty scholarships for the current year, and these have been allocated to fifteen private wireless training colleges in the United Kingdom. Application for consideration must be made in the first instance only to the principals of wireless training colleges, by whom the primary selection of candidates will be made.

The recommended candidates may be either partly trained students who find that they cannot meet the cost of further tuition, or applicants who wish to undergo tuition but are not in a position to pay the entire fee themselves.

The names of the recommended candidates will be submitted to the Marconi International Marine Communication Co., Ltd. for consideration and final selection, and those to whom scholarships are awarded will be notified. The Marconi Marine Company will then undertake to meet two-thirds of the tuition fees necessary to cover study to the standard required to obtain the Postmaster General's Certificate of Proficiency in Radiotelegraphy (2nd class), possession of which qualifies the student to go to sea as a radio officer.

The Physical Society's Competition for Apprentices and Learners engaged in work connected with the design and manufacture of scientific instruments is being opened this year to the following: employees of firms, research associations and institutions which have exhibited at the Physical Society's Exhibition at least once during the last three years; employees in the workshops or drawing offices of educational establishments; students attending recognized workshop or machine-drawing courses at technical colleges or schools, and selected bodies invited by the Council of the Physical Society.

The competition is designed to encourage craftsmanship and draughtsmanship in the scientific industry, and is held each year in connexion with the Physical Society's Exhibition. Each entry must be the unaided work of the competitor, but it may, however, have been carried out on the premises of the employer, at evening or day courses, or at home. Competitors must be under 22 years of age on March 31, 1953.

There are six classes under which work may be entered: scientific instruments and components; tools and gauges; optical components and systems; blown-glass and silica ware; pattern and functional scale models of scientific interest, and draughtsmanship. Radio and electronic chassis assemblies, model ships, engines, cars, etc., are excluded from the competition.

The judges will be appointed by the Council of the Physical Society. In judging the main emphasis in the craftsmanship classes will be on skill and accuracy, while in the draughtsmanship class the awards will be made on the usefulness of the drawings as constructional plans.

Three money prizes will be awarded in each class, as well as Certificates of Merit and of Honourable Mention. Full details are available from the Secretary, the Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

The British Kinematograph Society has inaugurated a Television Division of the Society to provide opportunities for closer co-operation between those engaged in kinematography and television. This division will operate similarly to the others already in existence, and enrolment will be open to all members of the Society who are interested in any branch of television technology. Further particulars are obtainable from the Secretary, the British Kinematograph Society, 164 Shaftesbury Avenue, London, W.C.2.

Brigadier E. J. H. Moppett, who was until recently Chief Inspector, Electrical and Mechanical Equipment, Ministry of Supply, has resigned his commission to become a director of Pye Telecommunications, Ltd.

RECENT BRITISH STANDARDS

British Standard for Dimensions and Nominal Voltages of Batteries for Valve-Type Hearing Aids. (B.S.966:1951). The British Standards Institution has issued a revision of B.S.966, which was first published in 1949 and was restricted to high tension batteries for hearing aids.

The present revision has been expanded to cover both high tension and low tension batteries and specifies the designation, nominal voltages, dimensions and methods of connexion. The test to be employed to determine the contact resistance of battery socket contacts is also given.

British Standard for Colour Code for Fixed Resistors for Telecommunication Purposes. (B.S.1852:1952). B.S.1852, "Colour code for fixed resistors for telecommunication purposes," sets out what has now become, with one or two minor divergencies, the internationally agreed colour code for resistors of the type often used for telecommunication purposes. The colour code has been in use in this country and elsewhere for several years and is based upon that originated by the Radio Manufacturers' Association of America.

The standard specifies the colours to be used and describes alternative methods of marking; the coloured band method is given as the preferred method. Tables giving an interpretation of the code are included.

The standard applies only to resistors for which colour coding is used to indicate resistance value and certain other characteristics, and does not preclude the continued production of resistors on which ratings are indicated in a non-coded form.

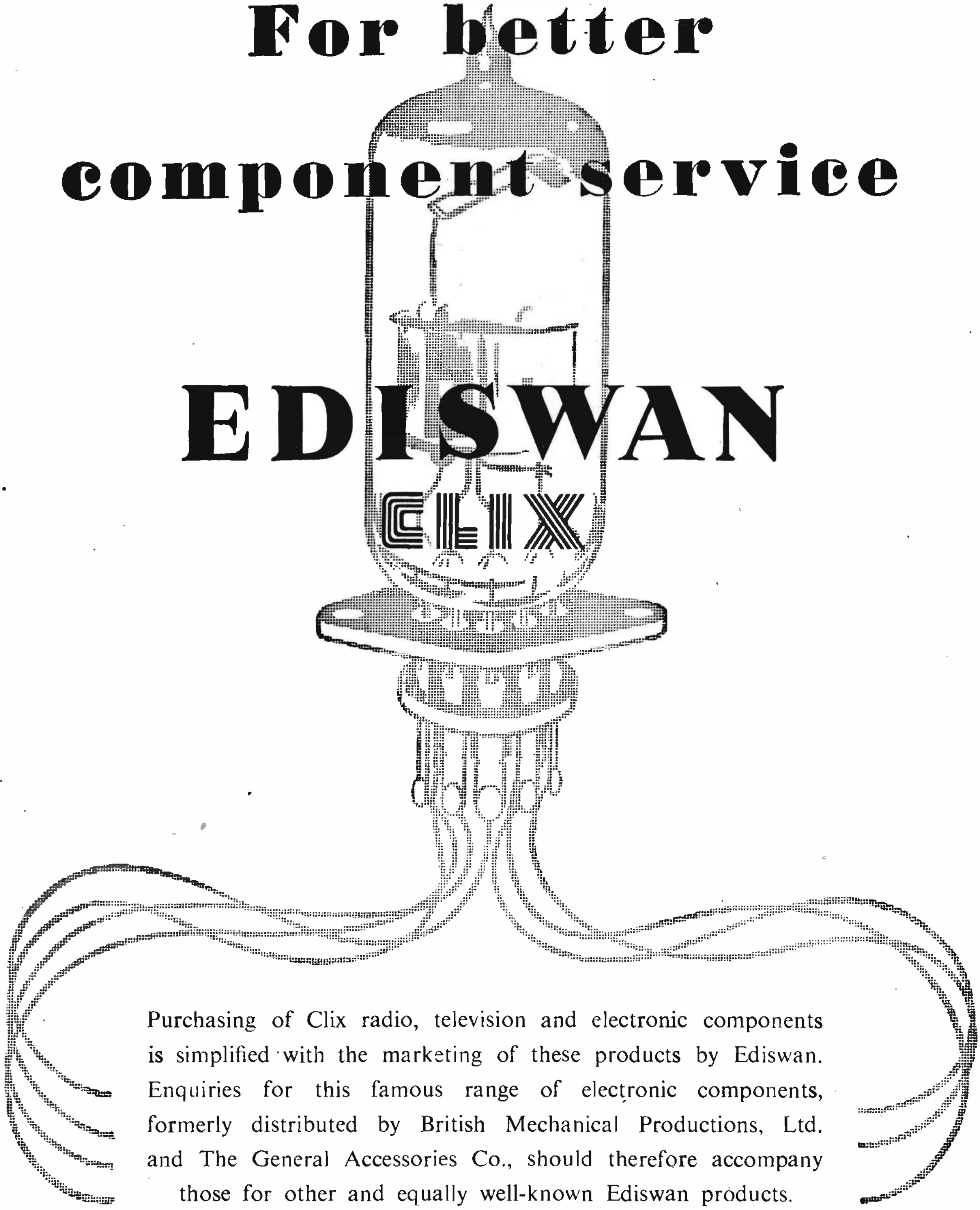
British Standard for Transformers for Cinematograph Sound Equipment (B.S. 1793:1952). The British Standards Institution recently issued a further British Standard in the series of specifications which are being prepared for electrical equipment used in cinema buildings and studios, namely B.S.1793 for audio-frequency transformers for cinematograph equipment. It covers transformers working over the audio-frequency range of approximately 30 to 10,000 cycles per second, and dealing with powers up to 1kVA.

Without imposing undue restrictions on details of design, it specifies such essential requirements for construction as will ensure safety in operation. Performance characteristics are specified, together with methods of test, including tests for transformers intended to be used under tropical conditions.

Copies of these standards may be obtained from the British Standards Institution, Sales Branch, 24, Victoria Street, London, S.W.1.

For better component service

EDISWAN



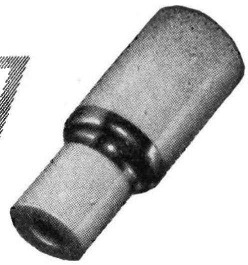
Purchasing of Clix radio, television and electronic components is simplified with the marketing of these products by Ediswan. Enquiries for this famous range of electronic components, formerly distributed by British Mechanical Productions, Ltd. and The General Accessories Co., should therefore accompany those for other and equally well-known Ediswan products.

THE EDISON SWAN ELECTRIC COMPANY LIMITED
155 Charing Cross Road, London, W.C.2, and branches

Member of the A.E.I. Group of Companies

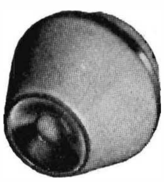
ER7

new



METALLISED CERAMICS FOR HERMETIC SEALS

Steatite & Porcelain Products present an outstanding advance in the technique of metallising ceramics; they can now offer ceramic bushes for hermetically sealed components free from all shortcomings common to earlier types of metallising



There are five important advantages of the new process:

1 The new metallising is robust and highly resistant to solution in any soft solder alloys.

2 Any method of soldering may be used, without precautions of controlled temperature and soldering time; no special skill in soldering is necessary for consistent results.

3 The new metallised ceramics may be repeatedly mounted and demounted: they may be removed from faulty or broken-down components and used again.

4 High melting-point soft-solders (such as silver-lead) may be used in assembly of these new metallised ceramics. Thus, all risk is eliminated of failure of the hermetic sealing during component assembly into equipment.

5 No gas or oil leakage can occur—the bond between the new metallising and the ceramic is stronger than the ceramic itself.

SEND FOR FULL DETAILS

The new metallising is applied to all the hermetic seals of the standard range (shown in catalogue No. 25, available on request). Special types, including multi-seals, can readily be produced to customer's requirements. Please write to us for further details. We shall be glad to answer any queries on the new metallised ceramics.

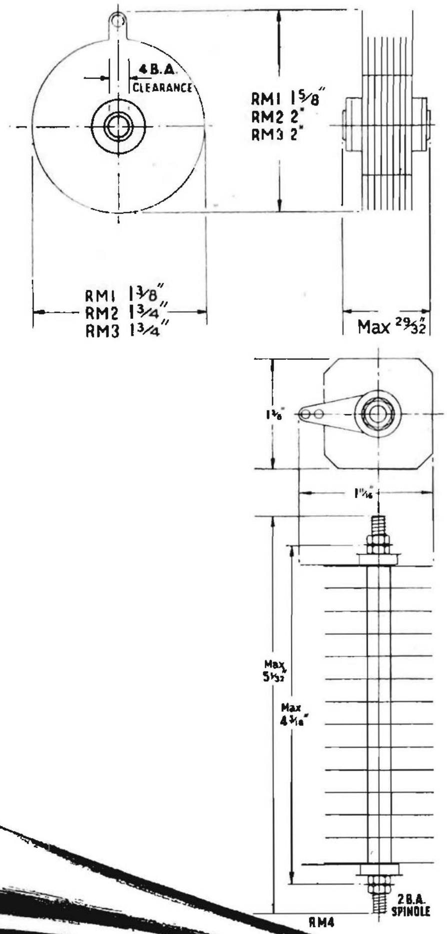
STEATITE & PORCELAIN PRODUCTS LTD

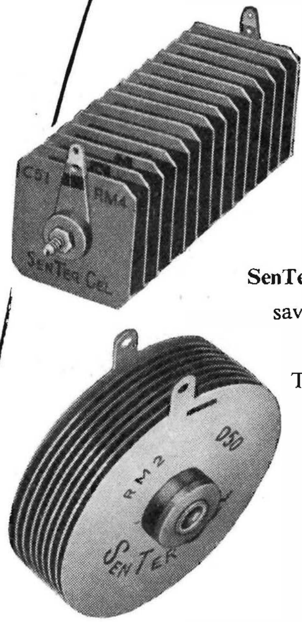
STOURPORT-ON-SEVERN WORCESTERSHIRE TEL: STOURPORT 111 GRAMS: STEATAIN STOURPORT

SP79

SELENIUM
SenTerCel
RECTIFIERS

miniature, lightweight
RECTIFIERS





Light, compact,
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save space . . . weight . . .
assembly time . . . cost.
Their many advantages
add up to this
imposing list:

- **Less wiring.**
- **Unlimited instantaneous overload such as the charging current of de-formed electrolytic capacitors.**
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- **No "warming-up" period.**
- **No valve-holder.**
- **Practically indestructible in normal service.**
- **No limit to size of electrolytic capacitor.**
- **Saves weight.**
- **Saves space.**
- **Low in cost.**

Study these **RATINGS**

TYPE	RM1	RM2	RM3	RM4
Maximum ambient temperature	35°C 55°C	35°C 55°C	35°C 55°C	35°C 40°C 55°C
Maximum output current (mean)	60mA 30mA	100mA 60mA	120mA 90mA	275mA 250mA 125mA
Maximum input voltage (r.m.s.)	125V	125V	125V	250V
Maximum peak inverse voltage	350V	350V	350V	700V
Max. instantaneous peak current	Unlimited	Unlimited	Unlimited	Unlimited
Weight	1 oz.	1.4 oz.	2 oz.	4.5 oz.

Standard Telephones and Cables Limited

(Registered Office: Connaught House, Aldwych, W.C.2)

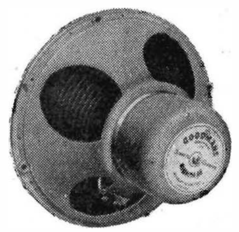
RECTIFIER DIVISION: Warwick Road, Boreham Wood, Hertfordshire.
Telephone: Elstree 2401 Telegrams: Sentercel, Borehamwood.

The Story so far . . .

Fourth of a Series telling the Story of Goodmans Loudspeakers.

In the first three of this series we have shown the very extensive process control and inspection measures carried out at *every* stage in the production of *every* cone, and we have stressed the vital importance of such control and inspection.
All the components comprising a completed loudspeaker are necessarily the outcome of careful research and development ; but none need more of the designer's attention than the cone. To develop a cone that will transduce to its air load the complex alternating currents passed through its associated speech coil with a minimum of "colouration" or harmonic distortion, "sub-harmonic" distortion, and all the troubles caused by non-linear elements, needs a great deal of often tedious work to determine its precise mechanical requirements. To do this, the designer must consider each part of the cone separately, then as a whole, and the whole must be as near to perfection as he can make it.
The cone surround must have exactly the right degree of compliance to control the bass resonance to within the required close limits. Its thickness, the shape and size of its corrugations, the nature of pulp to be used, and the treatment required are all involved : and while they are being determined it is necessary to ensure that the surround can handle the maximum amplitudes of the vibratory cone without ever imposing any non-linear restraint on it, and without any danger of its tearing, even though its thickness may be only a few thousandths of an inch.
The body of the cone constitutes the major task. The shape, or "profile" has to be determined, and it is largely upon this, together with the thickness, mass, and fibre structure of its material that the success of the cone in reproducing without discrimination the range of frequencies required of it depends. At the same time, the cone profile has a direct effect upon the polar diagram or "off axis" response of the completed loudspeaker, so this too has to be borne in mind in order that the higher frequencies shall not become sharply focused. Since the nature of the cone vibrations in the middle and upper frequency ranges may become highly complex, the designer's problems are formidable. When he has finalised the design of his cone, every part of it is given a detailed manufacturing specification, and it can go into production. The profile can be reproduced to the exact requirements easily enough after the necessary tools have been made, but all the work put into the cone design is wasted if any one of the other features is allowed to "drift" when quantity production starts.
So the routine of control and inspection at *all* stages, for *every* cone, is vital.
In conclusion, we may summarise this routine, which has been dealt with in previous announcements.
The Importance of Pulp is so great that all the attention given to the control of its fibre length and structure is well worth while and as The Cone Takes Shape the fibre density of the pulp in suspension must be closely checked to ensure that every finished cone shall have correct thickness, weight, and texture. Finally, after precision moulding, pressure treatment, and in some cases resin treatment, the completed cone is trimmed, checked for correct resonance, and carefully inspected before being built into a loudspeaker.
An Infinite Capacity for taking pains over all stages of production is the secret that lies behind the production of cones or diaphragms that will all always perform as well as the prototype.

AUDIOM 60



12" 15w. P.M. Loudspeaker

This famous all-purpose loudspeaker, of exceptional smoothness in response and performance, is specially recommended for high-power radio-gramophones, P.A. systems, and small cinemas. It is now available again on the home market.

Details will gladly be sent on request.

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GOODMANS INDUSTRIES LIMITED, AXIOM WORKS, WEMBLEY, MIDDX. *Telephone : WEMbley 1200*

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CUPRO-NICKEL NICKEL-CHROME

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These wires have been used for many years for winding resistances for instruments, control apparatus, etc.

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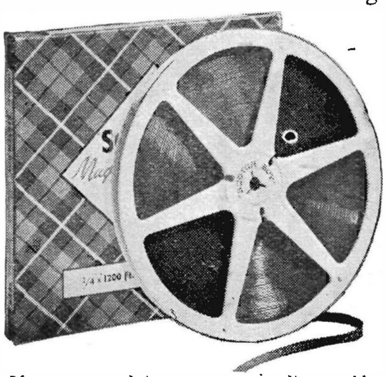

MAGNETIC DATA

Coercivity . . . . 240-260 Oersteds
Total Remanent Flux . . 0.4/0.5 lines ¼in. width
Uniformity throughout a reel . . . . . ±0.5 d.b.

FREQUENCY RANGE

50 c/s to 10 Kc/s at a playing speed of 7½ in./sec.

Medium coercivity gives a high signal output with an extended high-frequency response, whilst still retaining an easy erasure. Signal/noise ratio is high; transfer and distortion are negligible.

PLAYING TIMES (per track)

REELS	1⅞"/SEC	3¾"/SEC	7½"/SEC	15"/SEC
1200 Ft.	120 Min.	60 Min.	30 Min.	15 Min.
600 Ft.	60 Min.	30 Min.	15 Min.	7½ Min.
300 Ft.	30 Min.	15 Min.	7½ Min.	3¾ Min.

If you want advice on tape-recording problems, our entire technical knowledge is at your disposal.
Write to :— MINNESOTA MINING & MANUFACTURING CO. LTD., 167 Strand, London, W.C.2. *Telephone: TEMple Bar 6363*

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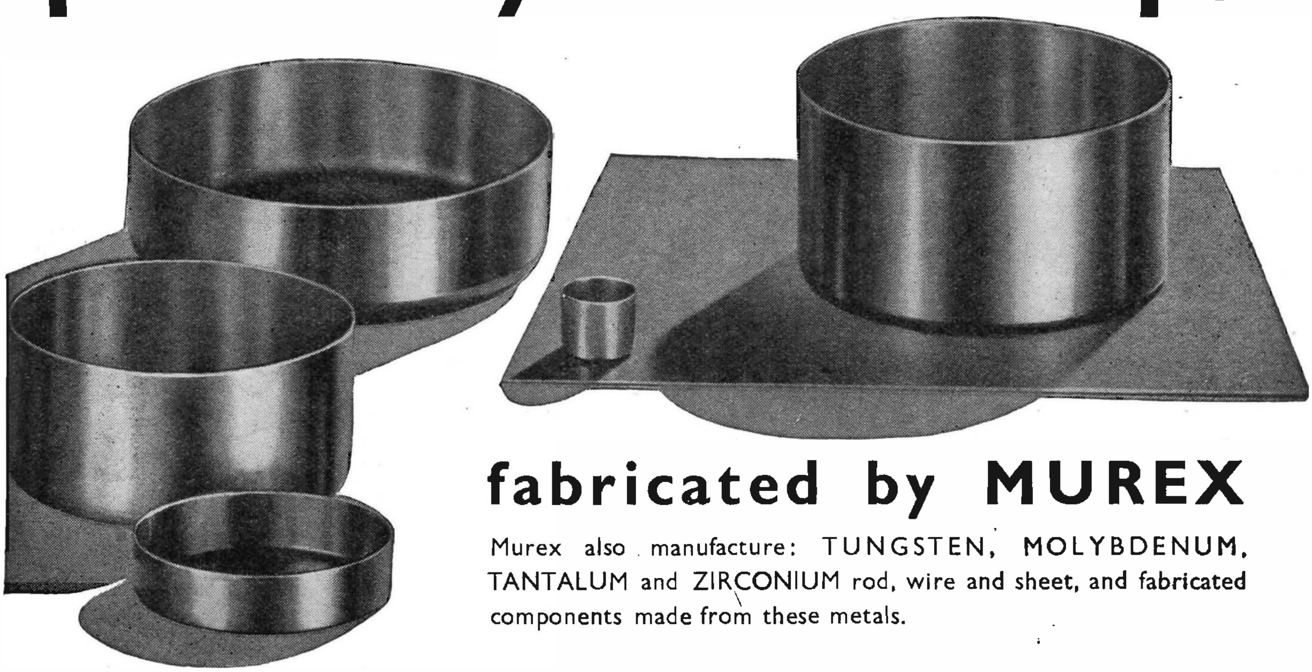
spun molybdenum cups



fabricated by MUREX

Murex also manufacture: TUNGSTEN, MOLYBDENUM, TANTALUM and ZIRCONIUM rod, wire and sheet, and fabricated components made from these metals.

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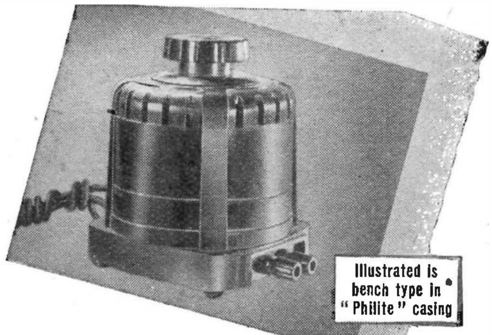
TECHNICAL DATA ON PHILIPS VARIABLE TRANSFORMERS



Illustrated is bench type in "Philite" casing

PHILIPS Variable Transformers, of a high efficiency, are available in 8 different types. Sturdily constructed and fitted with a graduated scale, they provide completely smooth control of secondary voltage from 0 V to 20% above the nominal primary voltage.

★ The Transformers given in the tables all have an input voltage of 220V 40-100 cycles. Models can however also be supplied for 110V or 130V input.

a= *overall diameter*
b= *depth behind panel*
c= *depth in front of panel*
d= *overall diameter*
e= *overall height*

Output ★	Secondary Voltage	Secondary Current	No-Load Losses	DESIGN Panel Mounting Type No.	Dimensions mm.			Bench Mounting Type No.	Dimensions mm.	
V.A.	V	A	W		a	b	c		d	e
260	0-260	1	6.8	84514	137	130	30	84515	137	165
520	0-260	2	9	84516	137	150	30	84517	137	185
1040	0-260	4	17	84518	187	190	30	84519	190	260
2080	0-260	8	25	84520	187	200	30	84521	215	272

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INDUSTRIAL X-RAY EQUIPMENT • ELECTRONIC APPARATUS • LAMPS & LIGHTING EQUIPMENT
ARC & RESISTANCE WELDING PLANT & ELECTRODES • MAGNETIC FILTERS • BATTERY
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(P1203)

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High quality Cathode-Ray Oscillograph recording instruments

ME54 Five-channel Recorder

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★ Specialised F.M. and D.C. Amplifiers.

★ Pick-ups for pressure, force, vibration, acceleration and other quantities.

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Be sure that the Quartz Crystal Units in your radio equipment are the best obtainable, for they are the most critical components

SALFORD ELECTRICAL INSTRUMENTS LTD · SALFORD 3 · LANCS

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3 WAY MIXER AND PEAK PROGRAMME METER

for recording and large sound installations, etc.

One milliwatt output on 600 ohm line (.775 V) for an input of 30 microvolts on 7.5—30 ohm balanced input.

Output balanced or unbalanced by internal switch. The meter reading is obtained by a valve voltmeter with 1 second time constant, which reads programme level, and responds to transient peaks.

Calibration in 2db steps, to plus 12db and minus 20db referred to zero level. Special low field internal power packs supplies 8 valves including stabilising and selenium rectifier, consumption 23 watts.

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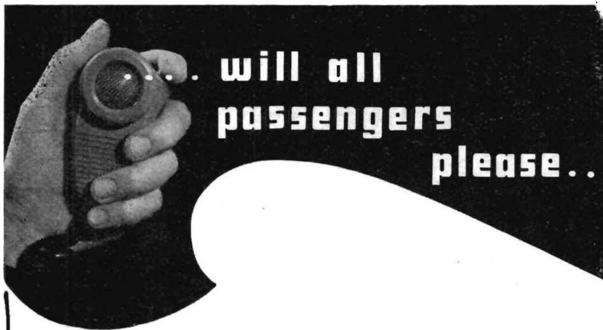

Sound travels better by VITAVOX

VITAVOX loudspeakers and microphones are designed for specialised application in the extensive field of sound reproduction. Thus the solution to your sound problem is primarily the selection of the right VITAVOX model to meet your specific needs.

The range extends from small hand microphones to two-way loudspeaker systems, and includes instruments to give the highest quality reproduction in all fields.

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The Delco range of British-made motors, generators, rotary transformers etc. for aircraft is designed to provide power for a wide variety of ancillary equipment including electronic control gear and radio.

Design approval is held from the Ministry of Supply Director of Instrument Research and Development, for D.C. Aircraft Electric Motors.

Available motors include totally enclosed, fan ventilated flame-proof and immersed types built to meet users' requirements and the relevant M.O.S. specifications. All motors achieve maximum output with minimum weight and many variations of standard designs are regularly manufactured to meet individual demands.

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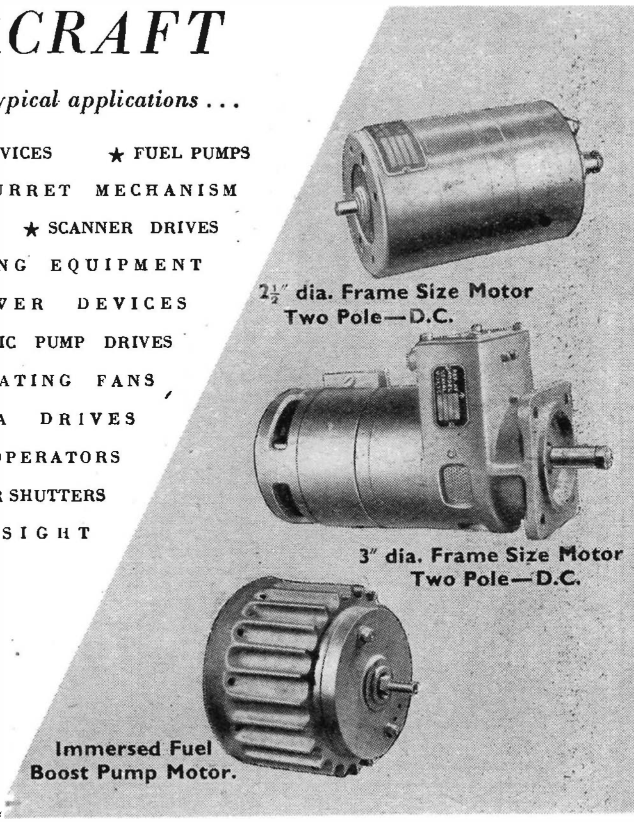
- ★ FLAP OPERATORS
- ★ RADIATOR SHUTTERS
- ★ BOMB SIGHT



DELCO AIRCRAFT MOTORS

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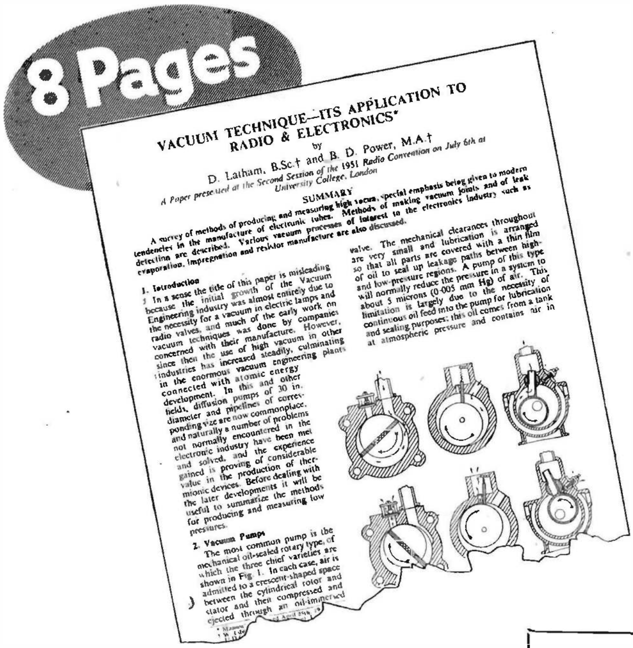
8 Pages

VACUUM TECHNIQUE—ITS APPLICATION TO RADIO & ELECTRONICS*

by

D. Latham, B.Sc.† and B. D. Power, M.A.†

A Paper presented at the Second Session of the 1951 Radio Convention on July 6th at University College, London

SUMMARY

TO VACUUM TECHNOLOGISTS

IN THE ELECTRONICS INDUSTRY

This technical paper presents an invaluable survey of different methods of producing and measuring high vacua, special emphasis being given to modern tendencies in the manufacture of electronic tubes.

Methods of making vacuum joints and leak detection are also given.

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A versatile instrument for use wherever rectangular voltage pulses are required

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De Havilland Propellers Ltd. require technicians for a Research Laboratory now being set up. The project is one which offers exceptional opportunities to physicists and to electronic, servo and instrument engineers and is unique in type and variety of research work involved. Senior and junior posts are available all offering good security and excellent conditions of employment.

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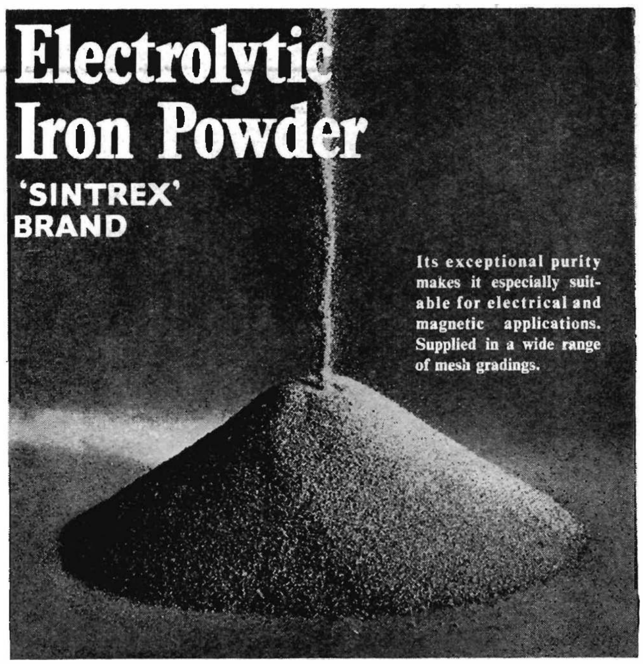

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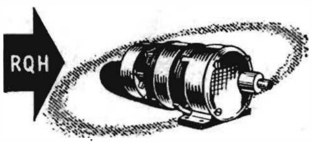
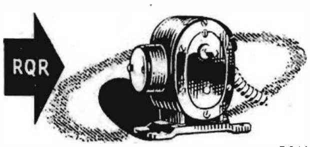
THE DRAYTON R.Q. is a miniature capacitor induction type motor with a current consumption at 230 volts, 50 cycles of 0.09 amps pf. 0.9. It is available:

R.Q.G. GEARLESS running at 2,700 r.p.m. continuously or intermittently in either direction or continuously reversed.



R.Q.H. GEARED for high final shaft speeds for continuous or intermittent running, forward or reverse.



R.Q.R. GEARED for continuous or intermittent running or reversing at speeds from 27 mins per rev. to 600 revs. per min., with or without self-switching up to 2½ r.p.m.

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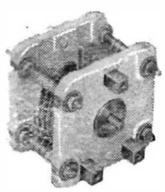
Miniature Trimmers, to High Voltage Transmitter Capacitors

For precision, stability, and long life, "Cyldon" superiority is recognised by all designers and users of electronic equipment



S Type Capacitor

This single-section split-stator capacitor is complementary to the multi-gang 'R' type and similarly is normally manufactured with stator terminals only to give series capacity characteristics, for use in push-pull circuits. High-grade ceramic insulation, silver-plated brass rotor and stator assemblies and fitted ball-races ensure long life and electrical efficiency.

Available in a variety of capacity and voltage combinations, the 'S' type capacitor will have a strong appeal to designers of High Frequency communications equipment.

● ***Full details** of the complete "Cyldon" range, and list of **Overseas** Agents, available from the Manufacturers:*

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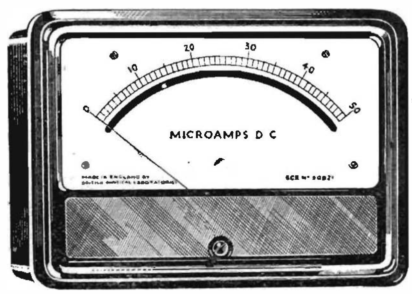
CAMBRIDGE ARTERIAL ROAD · ENFIELD · MIDDX. *Enfield 2071-2*

SENSITIVE PANEL MOUNTING METERS



SIZE	2½"	3½"	5"
RANGE	25 μA to 50A	10μA to 50A	10μA to 50A

(Prices on application)

S.50 types microammeters are stocked by M.R. Supplies Ltd. at New Oxford Street, W.C.1

All sizes available with MIRROR SCALE 1st Grade Accuracy.

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Electrolytics for chassis mounting

Since the introduction of these chassis mounting condensers, thousands of Amplifiers and P.A. equipments have been designed incorporating them.

The surge limiting feature of Wet Electrolytics is now of less interest owing to the greater load currents in common use today, but their indestructibility and freedom from possibility of short circuit are advantages which are often sought.

Dry Electrolytics have other advantages; greater capacity for a given size, larger ripple rating, ability to work at higher temperatures and adaptability for mounting in any position.

WET ELECTROLYTIC CONDENSERS

CAP. in μF.	PEAK WORKING VOLTS	SURGE VOLTS	BODY		TYPE NUMBER	LIST PRICE EACH
			L'gth	Dia.		
4	440	460	3	$1\frac{3}{8}$	812	8/6
8	440	460	$4\frac{1}{2}$	$1\frac{3}{8}$	802	10/-
8	500	525	$4\frac{1}{2}$	$1\frac{3}{8}$	805	12/-
16	440	460	$4\frac{1}{2}$	$1\frac{3}{8}$	802	12/-
32	320	400	$4\frac{1}{2}$	$1\frac{3}{8}$	809	12/-

DRY ELECTROLYTIC CONDENSERS

CAP. in μF.	PEAK WORKING VOLTS	SURGE VOLTS	BODY		TYPE NUMBER	LIST PRICE EACH
			L'gth	Dia.		
32	350	400	$2\frac{7}{8}$	1	312	9/-
4	500	600	$2\frac{7}{8}$	1	512	7/-
8	500	600	$4\frac{1}{2}$	1	512	8/-
16	500	600	$4\frac{1}{2}$	$1\frac{1}{2}$	512	11/6
32	500	600	$4\frac{1}{2}$	$1\frac{1}{2}$	512	17/6
8	600	700	$4\frac{1}{2}$	$1\frac{1}{2}$	922	15/-

All types of Wets and Drys can be supplied with insulating washers to isolate negative can from chassis where necessary.

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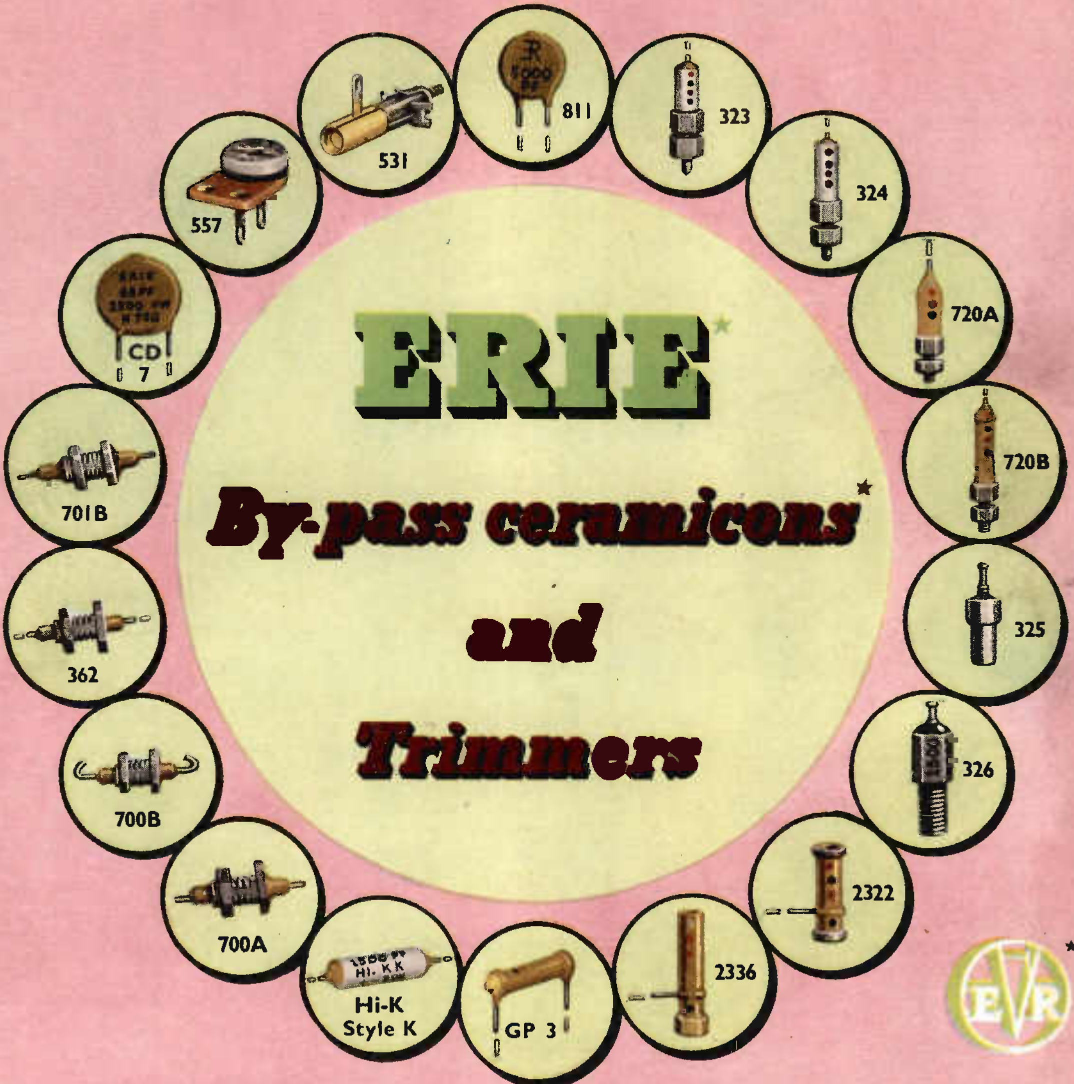
for VHF *applications*



ERIE CAPACITORS fulfil all requirements for efficient by-passing at very high frequency—compact design, low inductance and conservative voltage rating.

The range is the most complete at present available in this country and as can be seen from the selection which is illustrated, there are variations to suit all manner of purposes.

Disc units are supplied in values up to .01 MFD. Ceramic insulated tubulars up to 6000 PF. GP (phenolic insulated) and non-insulated Ceramicons★ up to 18500 PF. Stand-Off and Feed-Thru units up to 10000 PF. Trimmers : 531 from 0.5 to 5 PF. and from 1 to 8 PF. Trimmers : 557 from 5 to 30 PF.

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ERIE★ *Resistor Ltd*

★ *Registered Trade Marks*

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