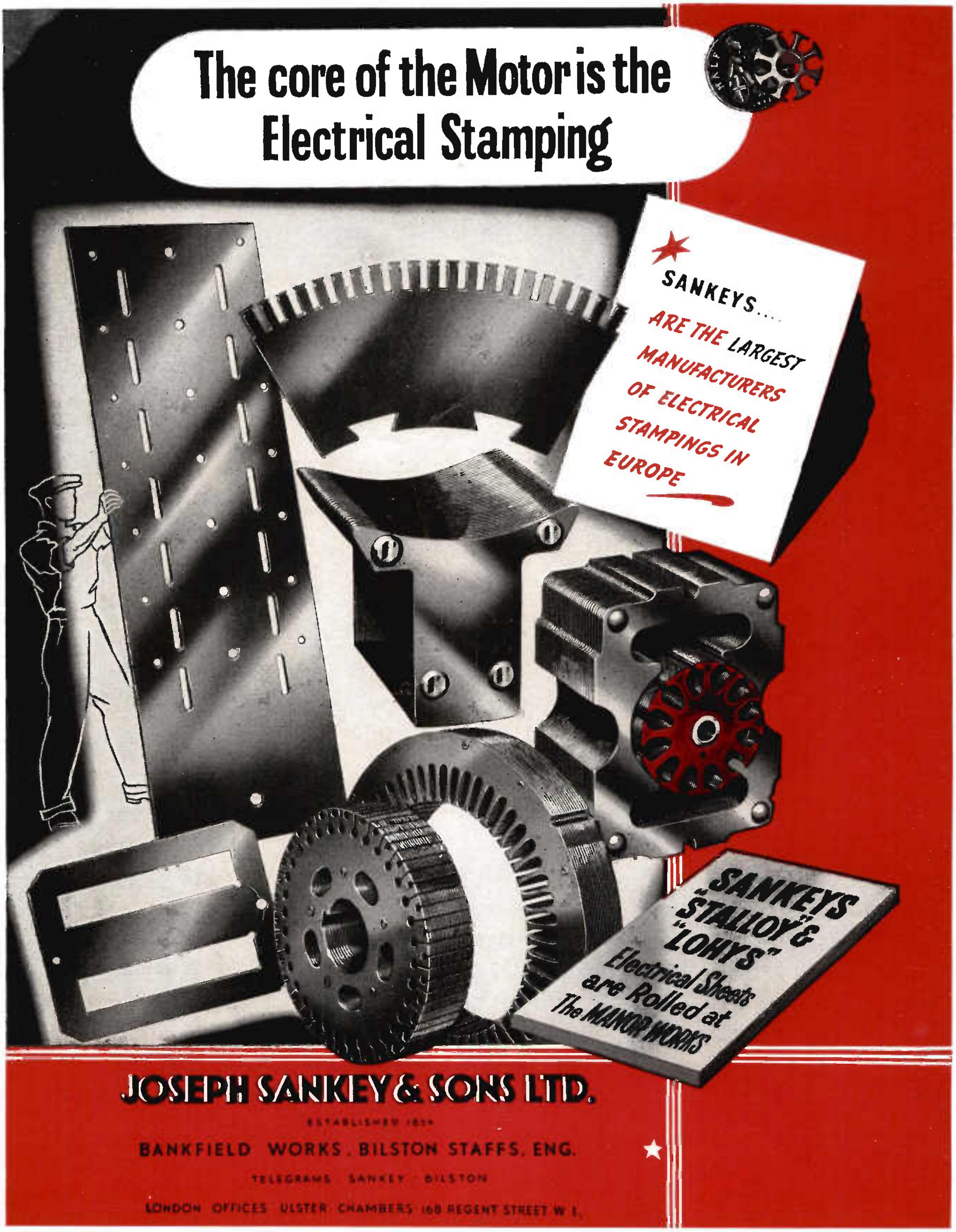
Electronic Engineering

MARCH 1952

TWO SHILLINGS



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CLASSIFIED ANNOUNCEMENTS

The charge or 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

ADMIRALTY. Applications are invited from Engineering, Electrical and Ship Draughtsmen for temporary service in Admiralty Departments at Bath. Candidates must be British subjects of 21 years of age and upwards, who have had practical Workshop and Drawing Office experience. Salary will be assessed according to age, qualifications and experience within the range £320-£545 per annum. Applications giving age and details of technical qualifications, apprenticeship (or equivalents) Workshop and Drawing Office experience, should be sent to Admiralty (C.E.II, Room 88), Empire Hotel, Bath. Candidates required for interview will be advised within two weeks of receipt of application. W 137

APPLICATIONS are invited by the Ministry of Supply for the following posts at an R.A.F. Signals Experimental Establishment in Bedfordshire. Senior Experimental Officer for the development of calibration procedure for radio test equipment and preparation of calibration publications. Duties will also include the calibration of sub-standards (against N.P.L. approved standards), specialist advice to Radio Equipment Calibration Centres and training of personnel for supervisory duties in these centres; liaison with the Radio Measurements Divisions in the Experimental Establishments of the Ministry of Supply. Ref. D17/52A. Experimental Officer for the calibration of transfer standards involving output and attenuation measurements. Ref. D18/52A. Assistant Experimental Officers (2) for the calibration of transfer standards (a) involving frequency and pulse measurements, and maintenance of the frequency standard and (b) involving bridge and miscellaneous measurements. Ref. D19/52A. Candidates for these posts should have a Higher National Certificate or equivalent qualification in applied physics, radio or electrical engineering. Experience in the duties outlined above is desirable. Salary will be assessed according to age and experience in the following ranges: Senior Experimental Officer (minimum age 35)—£742 to £960: Experimental Officer (minimum age 26)—£545 to £695, Assistant Experimental Officer—£240 (at age 18) to £505. Rates for women somewhat lower. The posts are unestablished. Application forms obtainable from Technical and Scientific Register (K), Almack House, 26 King Street, S.W.1. quoting appropriate reference number. Closing date 14th March, 1952. W 2472

APPLICATIONS are invited by the Ministry of Supply for a post in the Experimental Officer grade at an R.A.F. Signals Experimental Station near London. Duties include (a) the reconstruction of a radar landing aid and organisation of associated experimental investigation, (b) advice to R.A.F. and to contractors on associated problems. Candidates, who must be at least 26 years of age, should have a minimum qualification of Higher National Certificate in Electrical Engineering or equivalent qualification with a sound knowledge of electronics. A knowledge of pulse systems and associated techniques is desirable and experience in current electronic practice and laboratory techniques is essential. Salary will be assessed according to age and experience within the range £545 to £695 p.a. Rates for women somewhat lower. The post is unestablished. Application forms obtainable from Ministry of Labour and National Service Technical and Scientific Register. K. Almack House, 26 King Street, S.W.1, quoting D.6/52A. Closing date 14th March, 1952. W 2450

B.B.C. requires Engineers (minimum age 21) of British Nationality for duty at transmitter, studio, recording and television centres anywhere in U.K. Essential qualifications include Degree, Higher National Certificate, or equivalent, in Electrical Engineering. Promotion prospects. Salary £500 with annual increments to maximum £685. Applications to Engineering Establishment Officer, Broadcasting House, London, W.1, within 7 days. W 2455

CROWN AGENTS for the Colonies. Wireless Station Superintendent (Temporary) required by the Gold Coast Government Posts and Telegraphs Department for two tours of 18 to 24 months in the first instance. Commencing salary (including Overseas Pay and Temporary Allowance) according to qualifications and experience in the scale £834 rising to £920 a year with gratuity of £25 for each complete period of three months' service. Outfit allowance £60. Free passages. Candidates must possess a Higher National Certificate in Electrical Engineering or equivalent, and have had practical experience in two or more of the following fields: V.H.F. link systems; H.F. communication network; Frequency shift keying and teleprinter maintenance; V.H.F. and H.F. Direction finding systems; Aeronautical navigation aids (ground); Manufacture of light engineering equipment. 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 M.29100.B. The Crown Agents cannot undertake to acknowledge all applications and will communicate only with applicants selected for further consideration. W 2477

MINISTRY OF SUPPLY requires Engineer Technical Grade II in Malvern, Worcestershire. Qualifications, British. of British parentage, apprenticeship in radio or Electrical Engineering with good experience of setting up and testing electronic or electrical instruments. Possession of Ordinary National Certificate or equivalent qualification desirable. Knowledge of Service technical requirements an advantage. Duties, preparation of development and production test specifications for radar equipment. Salary, within range £540 (linked to age 30)-£645 p.a. Not established, periodical competitions for established pensionable posts may arise. Written applications giving date of birth and education, full details of qualifications and experience of posts held (including dates) should be addressed to Appointments Officer, Ministry of Labour and National Service, 1-6 Tavistock Square, W.C.1, quoting reference number K1.25. In no circumstances should original testimonials be forwarded. Only candidates selected for interview will be advised. W 2482

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 Limited. Worsley Bridge Road, Lower Sydenham. London, S.E.26. W 2483

RADIO TECHNICIAN required by The Bahrein Petroleum Co., Ltd., Persian Gulf. Capable of servicing and maintaining British and American short wave and ultra short wave radio telephone equipment both A.M. and F.M. Knowledge of electronics preferred. Age 25 to 35 years. Commencing salary £660 to £720 p.a. according to qualifications. In addition to salary the Company provide free board, air conditioned living accommodation and medical attention, on successive two year agreements with paid local and home leave. Living costs are low and there is a kit allowance and pension scheme. Write with full particulars of age, qualifications and experience to Box 5588 c/o Charles Barker & Sons, Ltd., 31 Budge Row, London, E.C.4. W 2466

TECHNICAL ASSISTANTS. Applications are invited from Radar and Electronic Technicians for appointment as civilian Technical Assistants, Grade III, in Anti-Aircraft Command units situated throughout Great Britain. Applicants must have experience of the repair and maintenance of Radar and Electronic equipment and hold the Ordinary National Certificate in Electrical Engineering or its equivalent. Salary range is £460-£575 (in the London area). Starting salary will be fixed according to age, qualifications and experience. Annual increases are payable subject to satisfactory service. Excellent opportunities for promotion to higher grades exist in all areas. Candidates should submit their applications in writing, stating age, qualifications, experience and area preferred, to Ministry of Labour and National Service, Milton Road, Wealdstone, Middlesex, quoting Order No. 14. W 2456

THE AUSTRALIAN NATIONAL UNIVERSITY, Canberra, A.C.T. The John Curtin School of Medical Research. Applications are invited for the post of Technical Officer in the Department of Physiology. Candidates must be skilled in the following fields: (a) Electronics, both in the construction of precision apparatus and in its maintenance. (b) Accurate work with electrical measuring instruments. (c) Fine work in metals and plastics. The selected candidate will be required to supervise both male and female assistants, and will have the status of Head Technician in the Physiology Department. The salary will be £A690 rising to £A865 by annual increments of £A25, plus cost of living allowance, at present £A102 per annum. The appointee would be required to take up duty in Canberra in September 1952, and fare to Australia (including those of wife and family) will be paid. Superannuation privileges are available. Applications and further inquiries may be made at the following address: The Administrative Officer in the U.K. The Australian National University, 27 Russell Square, London, W.C.1. Applications should include an account of the applicant's experience and qualifications. Closing date March 24th, 1952. W 2494

UNIVERSITY OF SYDNEY. Applications are invited for the following positions: Two Lectureships in Electrical Engineering (Power). Lectureship in Electrical Engineering (Electronics). The above vacancies mainly arise from a decision to establish permanent lecture-

The publishers apologise for any inconvenience caused to Messrs. British Insulated Callender's Cables Ltd. through the inaccuracies that occurred in the front cover advertisement of our February issue, which were the result of faulty printing.

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ships in place of temporary or part-time appointments. Salaries will be within the range of: £A650-£A50-£A1,000 with the addition in all cases of cost of living adjustment (at present £A159 males, £A121 females). Salaries will be subject to deductions under the State Superannuation Act. The commencing salaries will be fixed according to the qualifications and experience of the successful candidates. Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 5 Gordon Square, London, W.C.1. The closing date for the receipt of applications is 3rd March, 1952. W 2490

SITUATIONS VACANT

Advertisements under this heading are, where applicable, subject to the Notification of Vacancies Order 1952, with particular reference to Article 3 thereof.

A JUNIOR ENGINEER is required for work on magnetic amplifiers and airborne electronic equipment. An engineering degree or Higher National Certificate would be preferred, but a young man studying for either of these examinations would be considered. Guildford area. Write, giving qualifications and experience to Box No. W 2500.

A LARGE ENGINEERING firm in the London area has a number of vacancies for: (1) Senior Engineers. Ref. S.E.. (2) Junior Engineers. Ref. J.E. (3) Draughtsmen of all grades. Ref. D. The posts are in connexion with both important defence projects and long term private venture development work and are permanent and pensionable. These are first class opportunities and very adequate salaries are available. Write, quoting the Reference "T.E." and the category for which you wish to apply, to the Personnel Manager. Box No. 2473.

A NEW DEFENCE PROJECT of National Importance being undertaken by a well known Aircraft Company located in the Northern Outskirts of London, offers highly paid and interesting posts for suitably qualified applicants. Vacancies exist in Senior (salaried grades) and for Junior Engineers in various categories: (a) Physicists with experience in electronic problems. (b) Physicists with experience in optical work. (c) Electronic Engineers with Servo-Mechanism experience. (d) Electronic Engineers with experience of low frequency work and measuring systems. (e) Electrical Engineers with experience in small motor design and development. Applicants for Senior posts should possess a good University Degree and preferably should have some industrial experience. Applicants for Junior posts should have a good industrial experience, be qualified either by City & Guilds certificate or by Inter B.Sc. Write full details, qualifications, experience, age, salary sought to Box A.C. 65489 Samson Clarks, 57-61 Mortimer Street, W.1. W 2136.

A PROJECT ENGINEER is required by a well known firm of instrument makers, to direct the work of a section responsible for the layout and installation of specialised electronic equipment in aircraft. Applicants should be qualified Electrical Engineers, having had experience in, and enthusiasm for, this kind of work. They are asked to send full particulars of experience and training, stating salary required, to reference PE. Box No. W 2501.

A WELL-KNOWN Company invites applications for the following positions in its expanding Industrial Electronics Department located in the Midlands. 1. Product Engineers, to ensure that standard products are produced economically, and that design conforms to available processes. Applicants should have served an apprenticeship, hold H.N.C. (or equivalent) and have had several years' electronic production engineering experience. Drawing Office experience will be considered an advantage. (Ref. I.E.H.). 2. An assistant Mechanical Engineer to associate himself with the mechanical design of Industrial Electronic Equipment. Applicants should have a H.N.C. (or equivalent) and experience of light mechanical or electro-mechanical equipment. (Ref. D.I.H.). Please write giving full details and quoting appropriate reference to Box No. W 2462.

A WELL-KNOWN progressive Company has a vacancy in a rapidly expanding Commercial Department for a Technical Sales Executive for radio and radar apparatus. Candidates should have a good University Degree together with industrial and/or Government experience, a methodical nature with a flair for organisation and a genuine interest in the varied types of work undertaken by sales engineers. Importance will be attached to the adaptability of applicants and to their suitability to handle both technically and commercially a variety of equipments and to deal with customers at all levels. The post is permanent and has very good prospects for advancement. Applications will be treated in strict confidence. Please forward detailed personal information and salary required to Box No. W 2487.

A WELL-KNOWN progressive Company has a vacancy in a rapidly expanding Commercial Department for a Technical Sales Executive for Radio and Radar apparatus. Candidates should have a good University Degree together with industrial and/or Government experience, a methodical nature with a flair for organisation and a genuine interest in the varied types of work undertaken by sales engineers. Importance will be attached to the adaptability of applicants and to their suitability to handle both technically and commercially a variety of equipment and to deal with customers at all levels. The post is permanent and has very good prospects for advancement. Applications will be treated in strict confidence. Please forward detailed personal information and salary required to Box No. W 2401.

ACOUSTICS. Research and Development Engineers with good theoretical knowledge of acoustics. Design of high fidelity loudspeakers desirable but not essential. Good salaries right men. State age, qualifications, past experience and salary required. Goodmans Industries Limited, Axiom Works, Wembley, 1200. W 2452

AIRBORNE RADIO Communication Development Engineer. Marconi's Wireless Telegraph Company Ltd., have a number of vacancies for senior engineers possessing sound development and design experience in aeronautical equipment. Degree not essential if the candidate has long experience and other qualifications. Salary £700-£1,000 per annum depending upon qualifications. The positions are permanent and good prospects are offered. Pensions scheme. Applicants should state whether they have specialised in development of aircraft aerial systems, transmitters or receivers, etc. Write giving full details, quoting Ref. 875, to Central Personnel Services, English Electric Company, Ltd., 24/30 Gillingham Street, London, S.W.1 W 2498

AN INSTRUMENT MECHANIC is required for duties in the Electronics Section of the Research and Experimental Department. Applicants should possess a high degree of mechanical skill and be able to participate intelligently in both design and manufacture of small electro-mechanical devices. Experience in a similar capacity, whilst desirable is not essential. Write, stating age, experience and salary expected to the Personnel Officer, Saunders-Roe Limited, East Cowes, I.O.W. W 2323

APPLICATIONS are invited for the following posts in the Electronic Section of the Motor Industry Research Association—(1) Research Officer with Honours Degree, age 21 to 25 (starting salary £450-£575) and (2) Research Assistant with Higher National Certificate, or equivalent, age 25 to 30 (starting salary £450-£500), both to specialise in the study of—and construction of equipment for measuring Noise in Vehicles. Employment will be in the first instance at the Brentford Laboratory for about 12 months and subsequently at the New Laboratory now under construction at Lindley, near Nuneaton, Warwickshire. Reply to The Director, Motor Industry Research Association, Great West Road, Brentford, Middlesex, stating age, qualifications and experience, on which initial salaries will depend. W 1406

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. Applications must be detailed and concise, and will be treated as confidential. W 138

BRITISH TELECOMMUNICATIONS Research Ltd., a company associated with Automatic Telephone & Electric Co. Ltd., and British Insulated Callender's Cables Ltd. require a well qualified development engineer for work on Transmission Networks and Wave Filters. Applicants should have had previous experience in this field. An attractive salary will be offered to suitably qualified candidates. The position will be permanent and is covered by the superannuation scheme. Application should be made to the Director of Research, B.T.R. Ltd., Taplow Court, Taplow, Bucks, giving full details of qualifications and experience. W 2435

BERMUDA LABORATORY of Harries Thermionics (Overseas) Ltd., requires a valve mechanic, a junior physicist and a laboratory assistant. Salaries and fares on overseas contract. Opportunity in British-American research for first class men only. Box No. W 1418.

BRITISH ELECTRONIC PRODUCTS (1948) Ltd., have, at the present time, a number of vacancies for technical and administrative staff. The Company is a progressive organisation of moderate size, pleasantly situated, specialising in the development and manufacture of all types of industrial electronic equipment and in the application of electronic equipment to the needs of industry and the Services. It is associated with a leading electrical group and the positions, which are permanent, offer an unusual opportunity to applicants of the right type. The vacant positions are as follows: A. Senior Application Engineers with electrical engineering background and some knowledge of industrial electronic equipment, capable of discussing and interpreting the requirements of the customer and formulating complete schemes, involving electrical machines, contactor gear and electronic equipment. Applicants must be capable of preparing Specifications and conducting correspondence with the customer in relation to such projects. B. Application Engineers with electrical engineering background and interest in industrial electronic equipment to assist Senior Application Engineers and to deal on own initiative with more simple types of industrial application. Applicants must be capable of writing Specifications and conducting correspondence with customer. C. Design Engineers with electronic and/or electrical engineering background, capable of interpreting equipment Specifications in terms of existing circuit techniques, and passing detailed circuit information to the Drawing Officer, specifying component requirements, supervising mechanical design and preparing test specifications. D. Design Draughtsmen to prepare mechanical and electrical layouts and detailed drawings from design information in consultation with Design Engineers. E. Senior Development Engineers for Laboratory, to work on solution of specific industrial problems and in development of new circuit techniques. Applicants must be capable of original work and taking charge of development projects. Background on electronic circuit techniques and/or servo design essential. Junior Development Engineers for work in Laboratory under direction of Senior Development Engineers. Some knowledge of electronic circuit techniques and/or servo design desirable. G. Senior Test Engineers capable of taking charge of testing and the inspection of complex industrial electronic equipment without detailed supervision. Each equipment is of a specialised nature, and repetition testing is not involved. H. Junior Test Engineers for test and inspection of many types of industrial electronic equipment in small scale production. I. Service engineers for commissioning and maintaining all types of industrial electronic equipment in the field. Experience of electrical and/or electronic equipment desirable, and applicants must be prepared to travel to all parts of Great Britain or Overseas for short periods if required. Possession of car, for which a liberal running allowance will be made, would be an advantage. A vacancy exists under this category for an engineer capable of preparing Instruction Manuals from information supplied by Design and Development Engineers. J. Estimators for pre-costing of equipment under direction of Application Engineers. Knowledge of electrical or electronic engineering an advantage but not essential. A certain amount of clerical work in connexion with customer liaison would be involved, and applicants should be capable of conducting correspondence with customers if required. A superannuation scheme applies to all positions advertised. Applicants should write, in the first instance, indicating experience and salary required, to British Electronic Products (1948) Ltd., Rugeley, Staffs, marking the envelope "TAS Application," and should indicate the position in which they are interested by means of the reference letters. W 1409

BUSH RADIO LTD. have vacancies for Engineers as follows: Chiswick Laboratory—for Television Development and Telecommunica-

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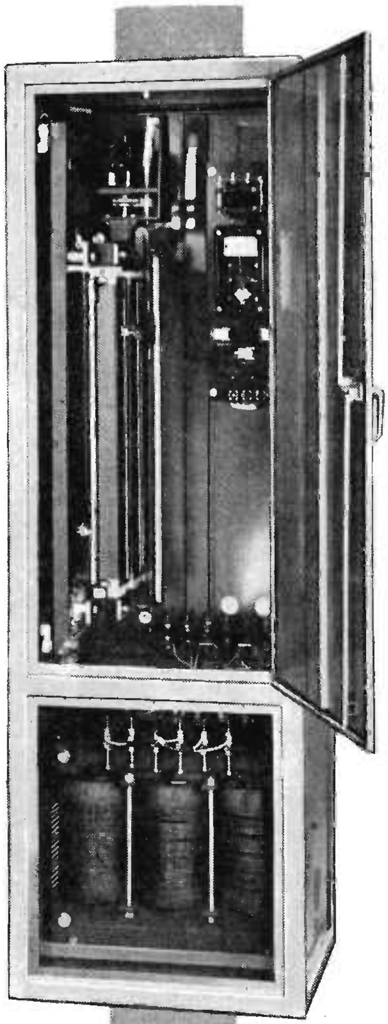
continued on page 4

Quality Components for INDUSTRIAL ELECTRONICS



VOLTAGE STABILISERS

The B.P.T. single phase and three phase voltage stabilisers maintain a *constant* voltage from a *fluctuating* supply regardless of fluctuation in load, load power factor, and normal frequency variations. Standard models—air and oil cooled—available from 3 to 75 kVA.

HERMETICALLY SEALED POTENTIOMETERS, MODEL R5

Wire wound—ohmic value range covers from 5 to 5,000 ohms. Rating 5 watts. Dimensions $1\frac{7}{8}''$ diameter $\times$ $1\frac{1}{4}''$. Weight 3 oz. (without knob). Withstands tropical damp and humidity and arctic cold—salt, dust and chemical laden atmospheres. Complies with inter-service standard specification RCL/131.

VITREOUS ENAMELLED RESISTORS

A wide range of vitreous enamelled resistors from 6 watt to 180 watt on 16 standard tube sizes with more than 20 alternative mountings, terminations and fittings. Fully tropical. Exclusive Bercohm craze free, non-porous, vitreous enamel gives stress-free winding and eliminates hot spots. Fully approved by R.C.S.C.

Other BERCO products include fixed and variable wire wound resistances and potentiometers, "Regavolt" infinitely variable auto-transformers, rotary rheostat potentiometers, stud switches, control knobs, etc., for all laboratory and industrial purposes.

BERCO

THE BRITISH ELECTRIC RESISTANCE CO. LTD.
Queensway, Ponders End, Middlesex
Telephone: HOWard 1492 *Telegrams: "Vitrohm" Enfield*

B.R.1071-BX

tions Development. Plymouth Laboratory—A Senior Development Engineer for Telecommunications work; also a Transformer Designer for development of small power transformers, pulse transformers, etc., and power supplies. Write giving full details of qualifications, experience and salary required to: Chief Engineer, Bush Radio Ltd., Power Road, Chiswick, W.4. W 2467

CHIEF INSPECTOR required by leading London Telecommunications Company. In addition to sound knowledge of modern line transmission and carrier practice applicants must have had wide experience of the testing of Components and electronic equipments by the latest methods. Initiative and the ability to lead and reorganise a fairly large department are other essential qualifications. Write giving fullest details of theoretical training, experience, age and salary required to Box No. 2469.

DESIGNER DRAUGHTSMAN aged 22/28, preferably with H.N.C. in mechanical engineering for old established firm of Precision Electrical instrument makers, Beckenham area. Candidates should have knowledge of electro-mechanical apparatus design and some workshop experience. Fullest details stating salary required to Box No. W 2488.

DESIGN ENGINEER required to take charge of Audio Frequency Section of Development Department of large Wire Broadcasting Company. Work would be in South West London. Write giving particulars of qualifications, experience and salary required to Box No. W 2478.

DEVELOPMENT ENGINEER experienced in design of Electrical Measuring Instruments and devices. Higher National Certificate essential. Write fully stating age, education and particulars of posts held to Box E.E. 632 at 191, Gresham House, E.C.2. W 2367

ELECTRONIC DEVELOPMENT ENGINEER required for work on Navigational Aids. Must be keen on flying duties. The position is permanent and pensionable. Apply in writing, giving details of age, qualifications, past experience and approximate salary required, to Personnel Officer, The Decca Navigator Company, Limited, Shannon Corner, Kingston-by-Pass, New Malden, Surrey. W 2499

ELECTRONIC ENGINEER with good academic qualifications and practical experience required for development work on vibration pick ups and associated equipment in South Bedfordshire area. Apply stating age, experience, qualifications and salary required, quoting reference S.4 to Box No. W 2492.

ELECTRONIC ENGINEER required by Instrument Manufacturing Company in South London, with 900 employees. Age 30-40 years. Must be qualified Engineer or hold Degree. Commencing salary not less than £1,250. Excellent opportunity for man with personality, initiative and drive. Please write in confidence to Box No. W 1423.

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 A.C. 68965. Samson Clarks, 57-61 Mortimer Street, W.1. W 2457

ELECTRONIC ENGINEERS are required for development of instruments in an Engineering Research Establishment on Tyneside. Applicants should possess a Degree or equivalent and have experience on similar work. Salary according to qualifications. Write Box No. 2465.

ELECTRICAL AND RADIO DRAUGHTSMEN required. Apply Employment Manager, Vickers-Armstrongs Ltd. (Aircraft Section), Weybridge, Surrey. W 2350

ENGINEERS with H.N.C. or equivalent required for work on industrial electronic instruments. Salary £500 and upwards p.a. Age 25-35. Box No. 1408.

ENGINEERS REQUIRED for Development, Servicing, and Instruction on Electronic Equipment. National Certificate Standard. Previous experience on Electronics or Radar desirable. Remuneration according to experience and qualifications. Apply: Construction Dept., The British Thomson-Houston Co., Ltd., Rugby. W 2463

E. K. COLE LIMITED (Malmesbury Division), invite applications from Electronic Engineers for permanent posts in Development Laboratories engaged on long-term projects involving the following techniques: 1. Pulse Generations and Transmission. 2. Servo Mechanisms. 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, Engineer 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 Pension Scheme after a period of service. Forms of application may be obtained from Personnel Manager, Ekco Works, Malmesbury, Wilts. W 2321

ENGLISH ELECTRIC VALVE CO., LTD., Chelmsford, have vacancies for young Engineers to work on radio valve design and development. Applicants should be of Degree standard. Whilst experience of this type of work is desirable, it is not essential and otherwise suitable candidates will be considered. Write giving full details, quoting Ref. 497E to Central Personnel Services, English Electric Co., Ltd., 24/30 Gillingham Street, London, S.W.1. W 2485

FERRANTI LIMITED, Edinburgh, have staff vacancies for Engineers or Physicists to work on the development of special valves to operate at microwave frequencies. Experience in this type of work is not essential but applicants should have an Honours Degree in Physics or Engineering. (1) Senior Engineers, with experience in charge of a development group, salary range according to qualifications and experience £1,000 to £1,600 per annum. (2) Development Engineers, salary £500 upwards per annum according to qualifications and any previous responsibility in development work. These positions carry good prospects for advancement in an expanding organisation. Contributory Pension Scheme. Apply quoting "VPL/E," giving full details of training, qualifications and experience to the Personnel Officer, Ferranti Limited, Ferry Road, Edinburgh. W 2378

FERRANTI LTD., 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.," state salary expected and give full details of training and experience in chronological order to the Personnel Officer, Ferranti Ltd., Ferry Road, Edinburgh. W 2468

GUIDED WEAPON PROJECTS at the Research and Armament Development Division of the Fairey Aviation Company, Limited, offer work of exceptional interest and opportunity to the following: Electronic Engineers experienced in micro-wave, pulse or communication techniques. There are both senior and junior vacancies and although a Degree or equivalent is normally required, applicants who lack such a qualification but who have considerable experience will also be considered. A Senior Electro-Mechanical Engineer for servo-mechanism analysis and automatic control design; electro mechanical, hydraulic or pneumatic. Accommodation assistance will be given in selected cases. Pension scheme. Good salaries. British born applicants wishing to be interviewed should send full details to the Manager, Dept. E., The Fairey Aviation Company Limited, Research & Armament Development Division, Heston Aerodrome, Hounslow, Middlesex. Engagements are subject to the Notification of Vacancies Order 1952. W 1426

H.F. HEATING ENGINEERS are required by the English Electric Company for their Industrial Electronics Department. These vacancies are for junior and senior Engineers with good experience of valve type H.F. Heaters. These are permanent and progressive appointments offering excellent opportunities for qualified engineers or those with sound practical experience of this class of work. Interviews can be arranged for Saturday mornings. Write giving full details and quoting Ref. 357C. to Central Personnel Services, English Electric Company, 24/30 Gillingham Street, London, S.W.1. W 2400

INSTRUMENT DRAUGHTSMAN required for design work on small mechanical and electro-mechanical devices. Interesting post for keen man with initiative. Apply, in writing, giving details of experience and qualifications, to K.D.G. Instruments, Ltd., Purley Way, Croydon, Surrey. W 2474

JUNIOR ENGINEERS required to assist in Research Development and Design of Electronic Calculating Devices. Some experience of Electronic Pulses and Counting Technique desirable but not essential. Applicants must have some experience of Research Development of Design Works in the Technical field. Qualifications: Degree in Physics or Engineering, Higher National Certificate or equivalent. Apply giving full particulars to the Labour Manager, Messrs. Vickers-Armstrongs Limited, Crayford, Kent. W 2373

JUNIOR INSTRUMENT ENGINEER. Higher National Certificate or equivalent. For electrical instrumentation schemes including remote indication and control. Write fully stating age and particulars of posts held to Box E.E. 631, at 191 Gresham House, E.C.2. W 2368

LADY TECHNOLOGIST or Graduate required for Engineering Test Department S.E. London, to be responsible for technical records. Ability to undertake technical investigations under guidance: knowledge of typing an advantage but not essential. A lady engineering student is also required. Write stating salary required, giving qualifications and previous experience, if any, to Box E.C.651, at 191 Gresham House, E.C.2. W 2374

LEADING LONDON COMPANY producing electronic and radar equipment requires a Chief Draughtsman for the Drawing Office of their research Laboratories engaged on interesting advanced work in this field. A man of first class experience with high design ability who has held a similar post successfully is required. A good salary and prospects are offered to suitable applicant having the necessary qualifications combined with initiative and enthusiasm. Housing assistance will be given if necessary. Pensions scheme. Write in first instance full particulars and state salary to Ref. ST. Box No. W 2496.

McMICHAEL RADIO LTD., require Senior Project Engineers in their Equipment Division Development Laboratory at Slough. Training and experience in the field of Applied Electronics (including Communications) and experience of working with Government Departments are the chief qualifications required. Salary will be commensurate with ability. Write stating age and full details of training, qualifications and experience to The Chief Engineer, Equipment Division, McMichael Radio Ltd., Slough, Bucks. W 2454

McMICHAEL RADIO LTD., require qualified Draughtsman with experience in the Mechanical Design of Radio and Electronic Instruments for the Government Services. Salary will be commensurate with ability. Write stating age, training, experience and salary required to The Chief Engineer, Equipment Division, McMichael Radio Ltd., Slough, Bucks. W 2453

MULLARD RESEARCH Laboratory in Surrey has a number of vacancies suitable for Honours Graduates in Physics, Electrical Engineering, Mathematics or for persons with other but similar qualifications for work on: 1. Line Communications. 2. Radio Communications. 3. Radar. 4. Computors. 5. Electronic Measurement and Control Devices. 6. Metal Physics. 7. Electron Accelerators. 8. Television. 9. Ultrasonics. Previous experience in one or more of these fields is an advantage but is not essential and equal significance is attached to the candidate's potential ability to apply himself to such work. In addition to these posts there are a number for which several years' experience in addition to academic qualifications is essential: 1. Development of carrier systems and filter design. 2. Communication receiver and transmitter design. 3. Research and development associated with television reception. Rates of pay are proportional to qualifications, experience and age. Publication of original work wherever possible is desirable and is encouraged. Successful candidates are elegible for the superannuation scheme. Applications should be made in the first case to the Personnel Officer, Mullard Research Laboratory, Redhill, Surrey. W 2480

CLASSIFIED ANNOUNCEMENTS
continued on page 6

MULLARD RESEARCH LABORATORY. Several Draughtsmen are required for work on electronic engineering projects. Some of the vacancies are for senior men of at least HNC standard who have spent a number of years in a Laboratory or Factory design department and are capable of original layout work. Other posts are for Detailing Draughtsmen capable of producing workshop drawings from such layouts. Salaries will be at current levels according to qualifications and experience. Prospects of promotion are good and the posts fall within the Company's Pension Scheme. Application forms Personnel Officer, Mullard Research Laboratory, Cross Oak Lane, Salfords, Nr. Redhill, Surrey. W 2363

MURPHY RADIO require Engineers with knowledge of Magnetic Amplifiers and Servo-mechanisms. Applicants should have the mathematical and engineering knowledge necessary to design systems and undertake original development work in this field. Apply giving full details to Personnel Manager, Murphy Radio, Ltd., Welwyn Garden City. W 2479

MURPHY RADIO LTD., have a vacancy for an assistant Engineer to be responsible for designing, ordering and maintaining testing and measuring instruments in their Electronics Development Laboratory. Application giving full details of qualifications and experience should be made to Personnel Manager, Murphy Radio Ltd., Welwyn Garden City. W 2495

MURPHY RADIO Ltd., offer the following vacancies in an expanding programme covering the field of domestic equipment and many branches of Electronic Development: (1) Senior Development Engineers having Degrees in Engineering or Physics with post graduate experience of equipment design who would be capable of leading a development team. (2) Development Engineers with similar academic qualifications having less or no industrial experience. (3) A Specialist Engineer with good academic qualifications having a sound knowledge of components and raw materials used in the Radio industry. This vacancy is only suitable for an applicant who is experienced in Electrical measurements and life testing of components. These posts are permanent and pensionable and offer good opportunities for advancement. Applications giving full details of experience and qualifications should be forwarded to the Personnel Manager, Murphy Radio, Ltd., Welwyn-Garden-City. W 2439

PHYSICISTS and Electrical Engineers. Interesting and varied work is available in a West London Research Department, for versatile qualified Physicists and Electrical Engineers on applied measurements—electrical, acoustic and mechanical. Good salaries are offered. Applicants, who should have several years' industrial experience of this type of work, are asked to forward full details of education, qualifications, experience, salary required to Box A.E. 780, Central News Ltd., 17 Moorgate, E.C.2. W 2476

RADAR Research and Development Laboratories in London area require Senior Engineers and Physicists at all grades up to that of Projects Leaders at salary scales of up to £1,200 per annum. Applications are invited from men with sound qualifications and extensive experience in the design of microwave radar systems and associated electronic apparatus. Assistance will be given in obtaining satisfactory local housing. Removal expenses from any part of the United Kingdom will be met. Please write in the first instance full details of experience, qualifications, age and salary required to Ref. GX. G.C. Box No. 2451.

RESEARCH and Development Engineers are required by British Telecommunications Research Ltd., a Company associated with The Automatic Telephone & Electric Co., Ltd., and British Insulated Callender's Cables Ltd., for work on long term development projects in the following fields: (a) Wide-band line communication. (b) V.H.F. and U.H.F. radio communication. (c) Electronic Switching and Computing. A number of posts with salaries in the range of £500-£1,000 per annum are available for suitably qualified engineers or physicists with experience in any of the above or allied fields. Further posts are available for technical assistants with salary in the range of £300-£600 according to qualifications and experience. Applications are also invited from Hons. Grads. in physics or electrical engineering who are considering careers in the research and development side of the telecommunications industry. There is a superannuation scheme and the company works a five-day week. Applicants joining early in the year will be eligible for full annual holidays. Application should be made to the Director of Research, British Telecommunications Research Ltd., Taplow Court, Taplow, Bucks, giving age and full details of education, qualifications, experience and approximate salary required. W 2436

SALES MANAGER required by large long-established Engineering Company. Must have first-class technical knowledge, preferably with University Degree in Electrical Engineering. Extensive experience of Electronics essential. Position offers wide scope for really live man possessing initiative and sales ability of high order. Write giving full details of age, education and positions held to Box EE.609, at 191 Gresham House, E.C.2. W 2358

SALES ENGINEER required to handle electronic equipment for the Metallurgical and Chemical Industries. Must possess University Degree or equivalent qualification. London area. Write giving full details as to age, previous experience, and qualifications to Box No. W 2470.

SCUNTHORPE HOSPITAL Management Committee. Immediate vacancy for Technician in Physics Department of Radiotherapy Centre to assist in instrument making, laboratory work, darkroom work and X-ray plant maintenance particularly. Applicants with knowledge of building and servicing electronic equipment preferred. Electrical Engineering qualifications and experience in other aspects of the work advantageous. Some radiation work will have to be undertaken. Whitley Council terms and conditions of service, present salary scale £410 by £15 (3) and £20 (1) to £475. N.H.S. Superannuation Scheme. Apply naming two referees to Secretary, The War Memorial Hospital, Scunthorpe, Lincs. W 2486

SENIOR AND JUNIOR Electronic Engineers required for development of Guided Missiles and other work of national importance. Good academic qualifications, a thorough knowledge of low frequency electronic circuits including D.C. Amplifiers, and practical design experience of lightweight electronic equipment are desirable. The posts are pensionable, and offer good scope for a man to learn and develop new techniques and advance his position. Apply to Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middlesex, giving full details of age, qualifications and experience and salary required. W 2440

SENIOR DESIGN Draughtsman required by manufacturers of electrical and electronic equipment. A thorough knowledge of materials and production methods is essential. The salary will be commensurate with qualifications and experience. Box No. 2471.

SERVICE ENGINEER required having good knowledge of reciprocating aircraft engines and reasonable knowledge of electronic practice. Preference will be given to applicants with experience of electronic engine performance analysis. Successful applicant will be required to travel in U.K. and Continent. Salary commensurate with qualifications and experience, but not less than £450 p.a. Superannuation scheme. Apply with full details of age, experience and salary required to the Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middlesex. W 2489

SOBELL INDUSTRIES, LTD., Hirwaun, South Wales, require: 1. Mechanical Designer Draughtsman. 2. Radio Television Development Engineers. Write stating qualifications, experience and salary required to Personnel Dept. W 2502

SPERRY GYROSCOPE Co., Ltd., Great West Road, Brentford, Middlesex, require Electro-Mechanical Engineers 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. W 2422

SPERRY GYROSCOPE Co., Ltd., Great West Road, Brentford, Middlesex, require Electronic Engineers with good academic qualifications and apprenticeship for development work. 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 age, experience and salary required to the Personnel Manager. W 2421

SUNVIC CONTROLS LTD., have vacancies at their Harlow factory for high grade laboratory personnel for development work on electronic and electromechanical process control equipment. Applicants should have H.N.C. or equivalent, and preferably some years' workshop experience. Houses will be allotted to successful applicants. Application in writing, giving full particulars, should be made to Chief Engineer, Sunvic Controls Ltd., No. 1 Standard Factory, Harlow, Essex. W 2458

TECHNOLOGISTS. Mechanical Engineers, Higher National Certificate or Graduates, 20-30 years, required for permanent appointments Mechanical Test Department, S.E. London. Must be capable of undertaking investigations into performance and analysing of test results of electro mechanical, mechanical and hydraulic mechanisms. Some test gear design from specification data and routine testing involved. Write stating salary required giving qualifications and previous experience to Box E.C.652, at 191 Gresham House, E.C.2. W 2377

TECHNICAL ASSISTANT required to study the performance of Geiger Counter Tubes and Cathode Ray Tubes, etc. Applicants should be of Intermediate standard. The post is open to young people of either sex and offers good opportunities on the technical side of an expanding organisation in S.E. London. Staff Pension Scheme. Applicants should give age, experience and salary required. Box No. 1411.

TECHNICAL ASSISTANTS required for interesting work in connexion with High Frequency Cable Testing. Previous experience not essential, but applicants should hold National Certificate or equivalent qualifications. Apply in writing to Siemens Brothers & Co., Limited, Ref. 423, Woolwich, London, S.E.18. W 2484

TECHNICAL LIBRARIAN required by British Telecommunications Research Ltd., Taplow Court, Bucks. A knowledge of telecommunications, electrical engineering or physics approaching Degree standard is required with preferably some technical library and typing experience. Some knowledge of foreign languages useful. Salary initially £350-£550 per annum depending on qualifications and experience and subject to annual review. Pension fund, 5-day week and canteen. Application forms may be obtained from the Director of Research. W 2464

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 2491

UNIVERSITY OF LONDON Postgraduate Medical School. Electronics Engineer required to develop Biophysics equipment for medical research. Applicant should hold the Higher National Certificate or equivalent. Salary, depending on qualifications up to £580, with superannuation. Applications, age and details, to the Secretary, Postgraduate Medical School, Du Cane Road, W.12, by March 8th. W 2475

YOUNG ELECTRONICS and Telecommunications Engineer required as Technical Assistant in London Chartered Patent Agents' Office. £400 per annum to commence. Will be trained with view to qualifying in profession. Apply to Box No. W 1407.

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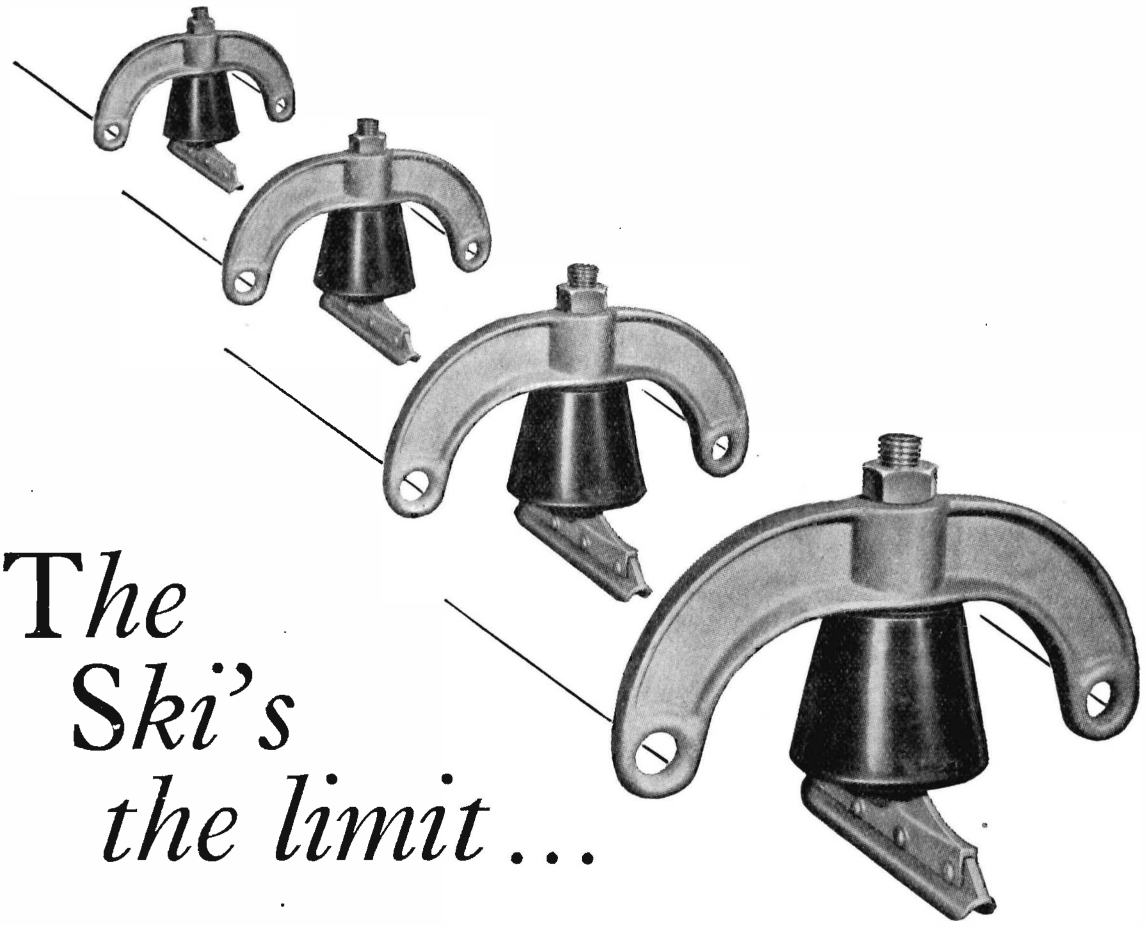
Advertisements under this heading are, where applicable, subject to the Notification of Vacancies Order 1952, with particular reference to Article 3 thereof.

ADVERTISER, 24 years' experience in Radio Communication, Assoc. Brit. I.R.E., City and Guilds Final Radio Communication plus Technical Electricity, Final International Technical Certificate in Mathematics, Electrotechnics and Radio Communication (equivalent 3rd year B.Sc.) seeks post in design of, or other work, in Communication Apparatus of all types. Go anywhere preferably Southern Rhodesia, South Africa, New Zealand or Australia. Fully willing undergo probationary period with confidence. Box No. W 1419.

CLASSIFIED ANNOUNCEMENTS
continued on page 8



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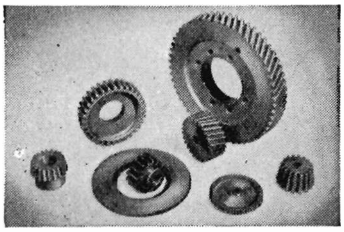

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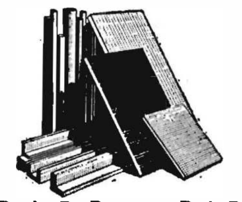

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RESEARCH into the use of servo-control equipment in industry is rapidly expanding and it will be of interest to manufacturers to hear that we are in a position to offer for immediate delivery many types of Magslip and Selsyn elements at a considerable reduction on current prices. Among the many applications of Magslips we may mention use as a flexible shaft, for remote indication, remote power control, remote handling (e.g. of radioactive materials) and electrical computation. Our large stocks include Magslip transmitters, receivers, resolvers, hunters, follow through transmitters and many other special types. Linear A.R.L. Ipots No. 1 Mk. 1 are also available. All our equipment is guaranteed. Home and export enquiries invited. Illustrated brochure and price list from: Servotronic Sales, Abbey Road, Belvedere, Kent. Telephone Erith 2479. W 2447

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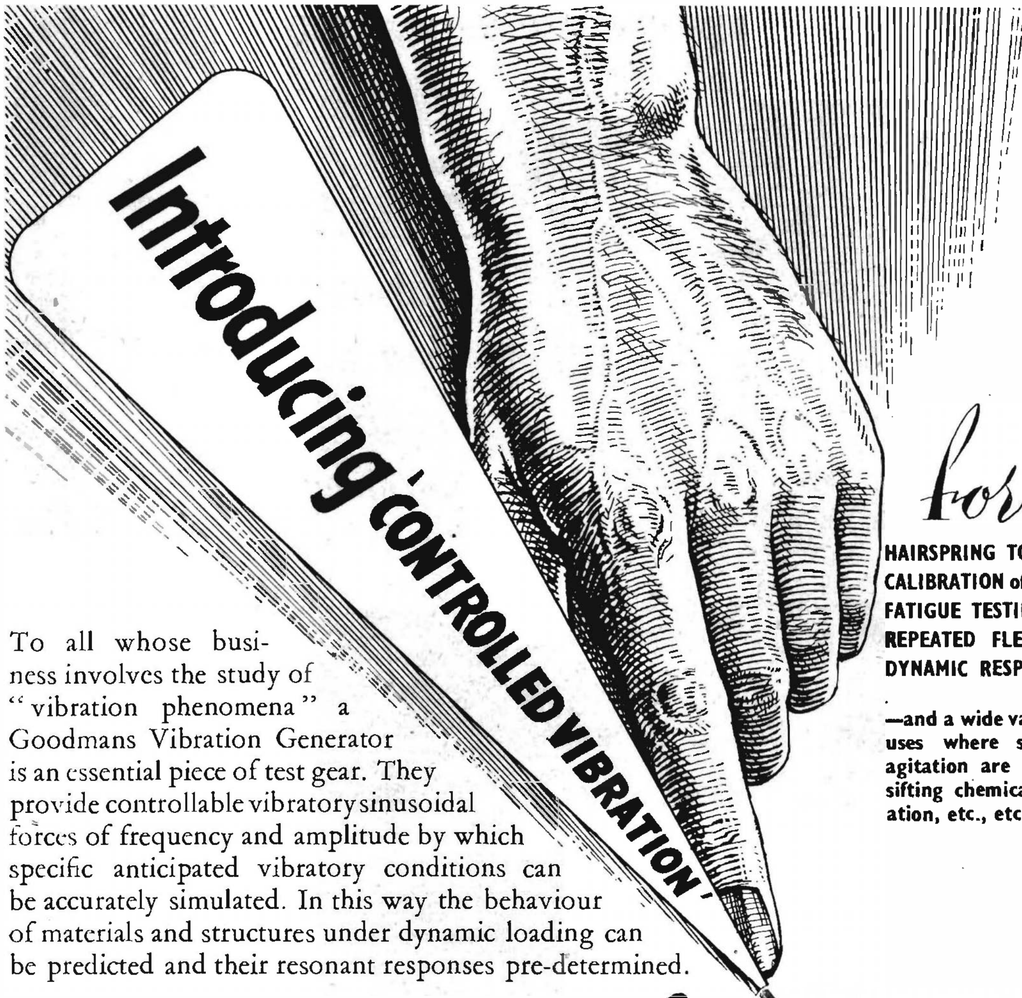
PATENTS

THE PROPRIETOR of British Patent No. 561,434 relating to Electric Relay Systems for the Automatic Control of variable Conditions, is desirous of arranging by licence or otherwise on reasonable terms for the manufacture and commercial development of the invention. For particulars address in the first instance to Matthews, Haddan & Co., 31/32 Bedford Street, Strand, London, W.C.2. W 2459

THE PROPRIETOR of British Patent No. 564,193 relating to Electronic Translating Devices, is desirous of arranging by licence or otherwise on reasonable terms for the manufacture and commercial development of the invention. For particulars address in the first instance to Matthews, Haddan & Co., 31/32 Bedford Street, Strand, London, W.C.2. W 2460

THE PROPRIETORS of British Patent No. 564,194 relating to Electronic Translating Devices, are desirous of arranging by licence or otherwise on reasonable terms for the manufacture and commercial development of the invention. For particulars address in the first instance to Matthews, Haddan & Co., 31/32 Bedford Street, Strand, London, W.C.2. W 2461



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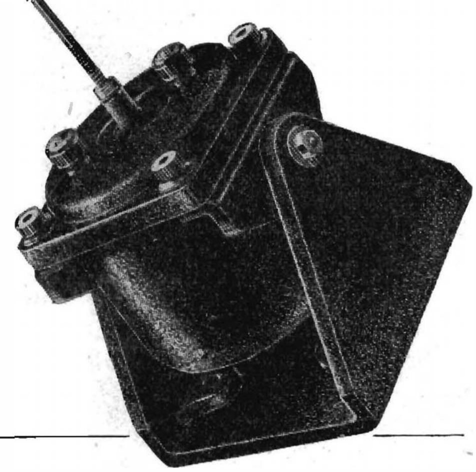

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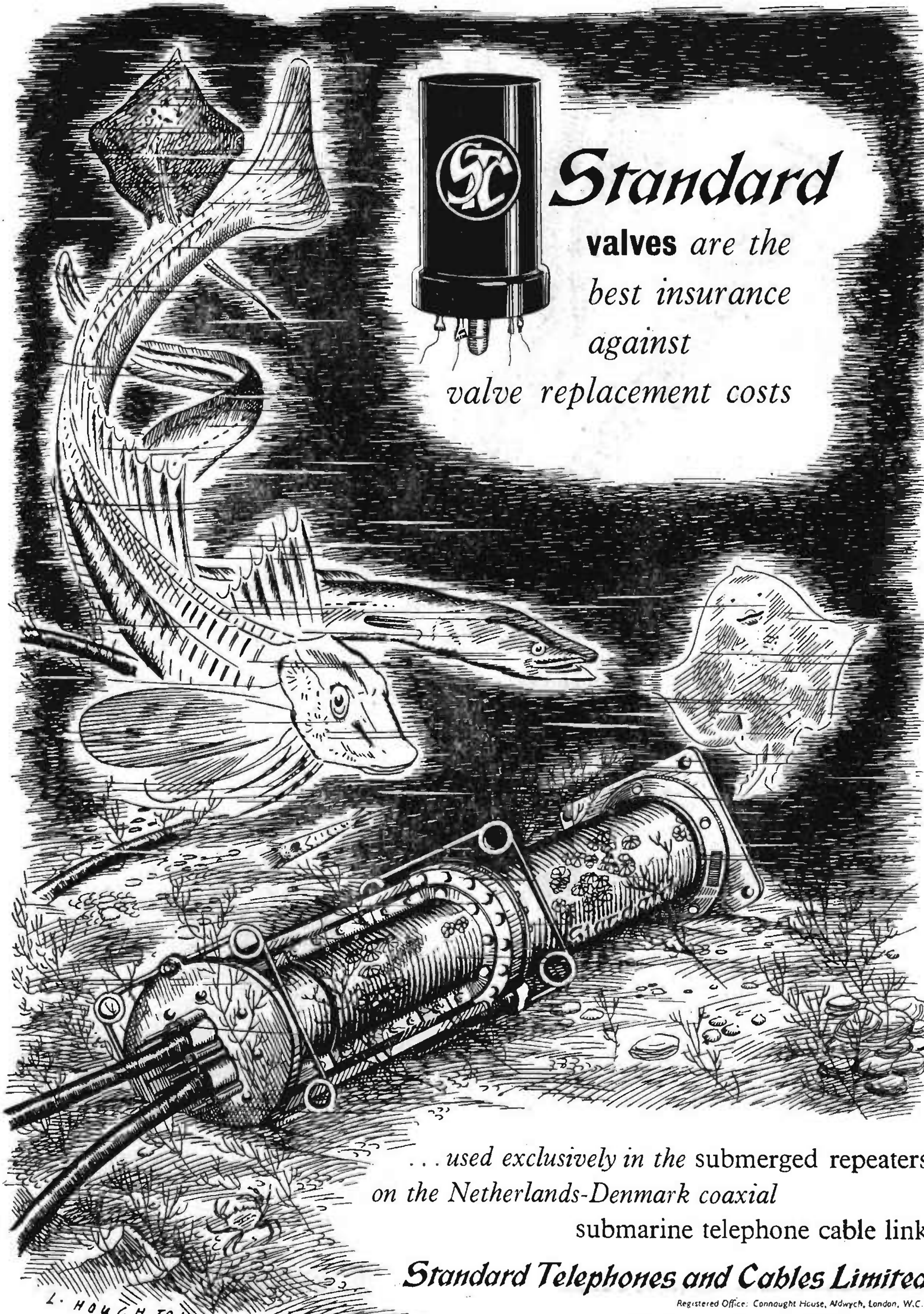
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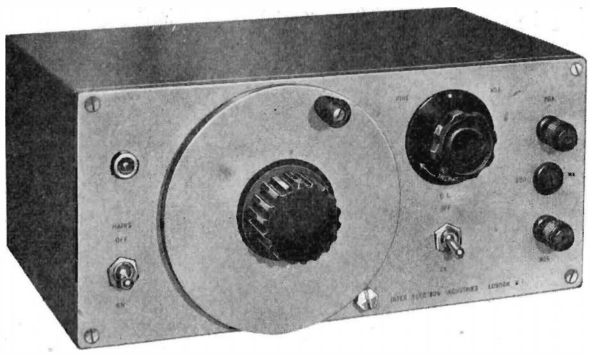

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REMOTE CONTROL UNIT

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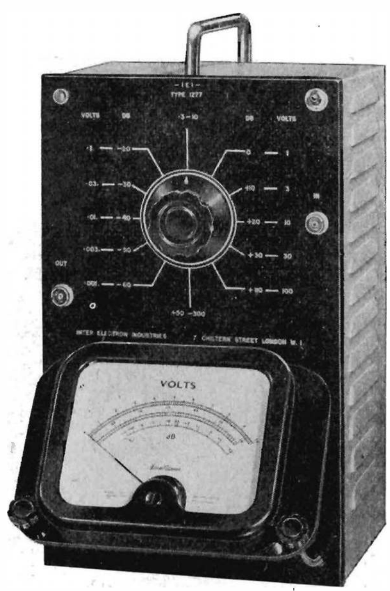

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100-KM	2000 va.	115	15 a.	17.5 a.	0-115		20 watts	18 12 0
100-L	2000 va.	230/115	8 a.	9 a.	0-230		25 watts	17 17 0
100-LM	2000 va.	230/115	8 a.	9 a.	0-230		25 watts	18 12 0
100-Q	2000 va.	115	15 a.	17.5 a.	0-135		20 watts	18 9 0
100-QM	2000 va.	115	15 a.	17.5 a.	0-135		20 watts	19 4 0
100-R	2000 va.	230/115	8 a.	9 a.	0-270		30 watts	18 9 0
100-RM	2000 va.	230/115	8 a.	9 a.	0-270		30 watts	19 4 0
100-LH	1200 va.	480/240	2 a.	2.5 a.	0-480		25 watts	21 15 0
500-L *	1450 va.	180	8 a.	9 a.	0-180		25 watts	17 17 0
2000-K †	1000 va.	125	8 a.	9 a.	0-125		25 watts	17 17 0

* For 500 cycles   † For 2,000 cycle service   * All "VARIAC" prices plus 10% as from 1st June, 1951

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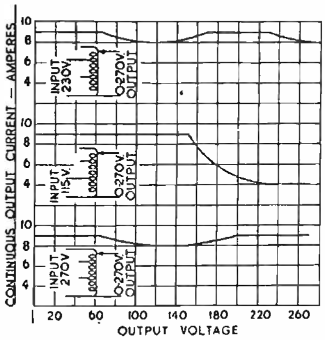
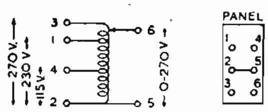
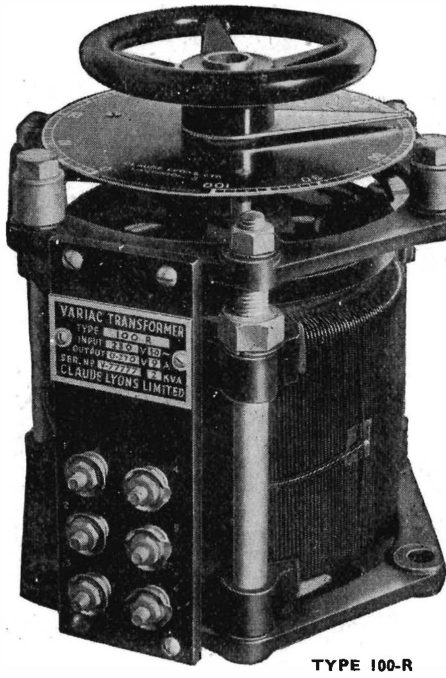




OUTPUT CURRENT CHARACTERISTIC AND TERMINAL ARRANGEMENT FOR TYPE 100-R TRANSFORMER



TYPE 100-R

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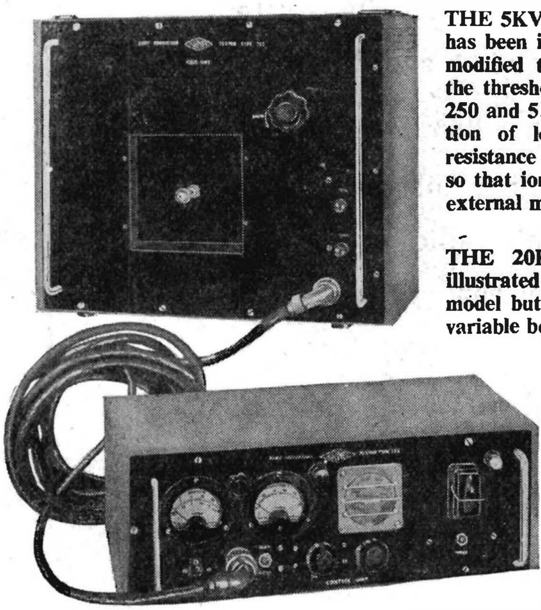
An important feature of the testers is their high source impedance which, by limiting the current to a low value, ensures the maximum safety for both operator and equipment under test.



THE 5KV IONISATION TESTER, TYPE 732, illustrated above, has been in production for over three years, and has recently been modified to incorporate several improvements. Besides indicating the threshold voltage at which ionisation occurs between the limits 250 and 5,000 volts, the instrument now gives a direct meter indication of leakage currents, and enables the value of insulation resistance to be determined. Furthermore, an output jack is provided so that ionisation may be detected by the use of headphones or an external meter.

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INTRODUCE

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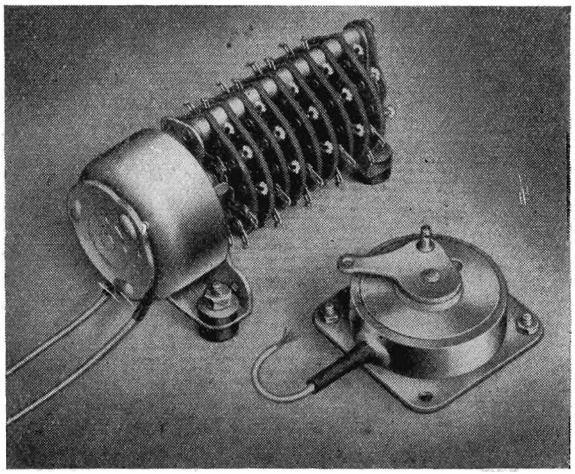
THE N.S.F.-LEDEX ROTARY SOLENOID is a compact, robust and efficient electro-mechanical device which provides a powerful snap-action rotary movement of substantially constant torque over the whole of the angular stroke.

The Rotary Solenoid was originally developed in the United States during World War II as the result of an urgent demand for a dependable bomb release with a high speed action. In the course of long and extensive use in many types of American fighter and bomber aircraft, it proved itself capable of standing up to all the arduous working conditions imposed upon it.

Evolution of the Rotary Solenoid was soon afterwards followed by the development of the LEDEX CIRCUIT SELECTOR, which employs the Rotary Solenoid in conjunction with OAK Switch sections. Many thousands of these units have since been embodied in a wide range of equipment using remote control switching.

In arriving at the decision to manufacture LEDEX ROTARY SOLENOIDS and CIRCUIT SELECTORS in Great Britain, N.S.F. were inspired by the fact that the large quantities that have been produced in the United States have been giving reliable and efficient service over an extensive period.

Besides achieving success in bomb release mechanisms, the LEDEX ROTARY SOLENOID has subsequently been employed with great success in aircraft and automobile radio equipment; sports-



ground scoreboards; totalisators; accounting machines; machine tool controls; co-axial switch drives for television, tele-communications and radar; hydraulic valve operation; and auxiliary fuel tank release apparatus on jet fighter planes.

We at N.S.F. are confident that these and all present applications of LEDEX ROTARY SOLENOIDS and CIRCUIT SELECTORS represent a very small percentage of the total potential uses in both the mechanical and electronic fields. We therefore earnestly invite all Engineers who feel they could make use of these devices in any project they may have under development to contact us, in order that they may have full benefit of our accumulated experience.

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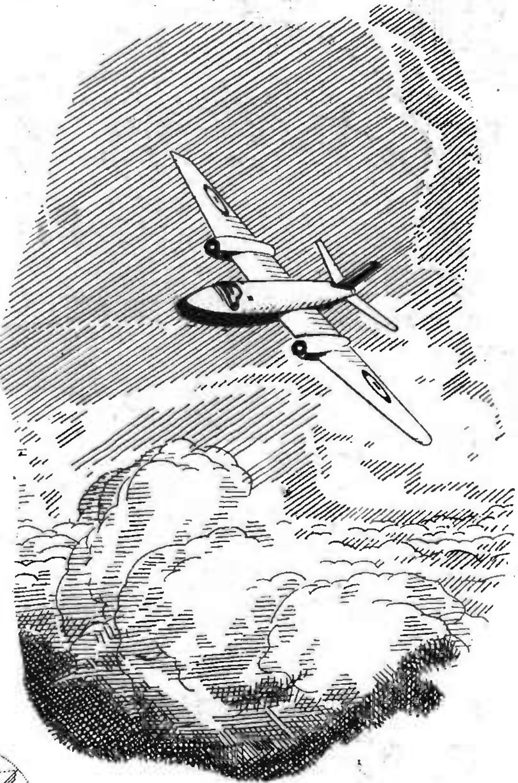

Marconi came into a world in which communications were adolescent. When he left it, the marvels of radio were a commonplace. His name had achieved immortality; his work was established in the service of mankind. It is therefore no coincidence that the Company which he founded should supply communication and navigation equipment for aircraft like the Canberra and Comet, which are the most advanced of their class in the world.

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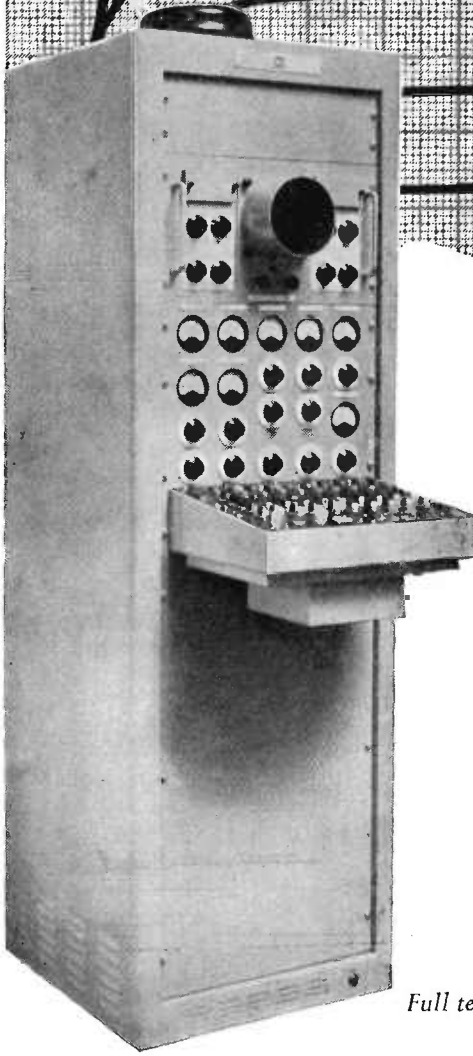

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Electronic Engineering

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

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Contents

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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.

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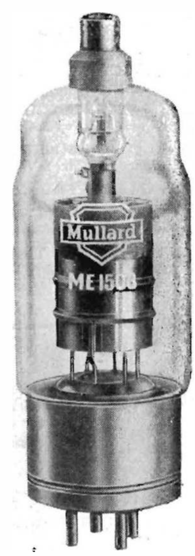
For special applications where extremely rapid rates of current rise are required, as, for example, in the modulation of radar transmitting systems, there is also a hydrogen-filled thyratron, the ME1503. This valve, characterised by its very low ionisation and de-ionisation time, is the first of a group 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	Va (pk) max. (KV)	PIV max. (KV)	ia (pk) max. (A)	Ia (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

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Electronic Engineering

Vol. XXIV. **MARCH 1952** No. 289.

Commentary

IN the middle of January this year, the Royal Commission on Awards to Inventors announced its recommendations to the Treasury " in respect of claims in connexion with the invention and development of radar."

As is now known, awards totalling £94,600 were made to 21 claimants of whom Sir Robert Watson-Watt, F.R.S., received the largest individual award of £50,000 for his " initiation of radar and his contribution to the development of radar installations."

After reading the early history of the radar development prior to the war it seems to us that there is a remarkable similarity between Sir Robert Watson-Watt's memorandum of February 1935 and the now famous letter to " Nature " of Campbell Swinton in 1908.

Campbell Swinton's suggestions of course had to wait a number of years before they could be brought to fruition, but once Sir Robert Watson-Watt's suggestions had been accepted he was able to collect together a team of scientists and demonstrate his theories with scarcely a day's delay:

There were of course earlier attempts to utilize the reflexions of radio waves and in 1928 a scientist at the Signal School at Portsmouth put forward a scheme for the detection of distant objects by observing the radio waves reflected from them using either frequency modulated or " periodically interrupted waves." This was followed in 1931 by a suggestion made by two of the recipients of the recent awards—W. A. S. Butement and P. E. Pollard—then at the Army Signals Experimental Establishment at Woolwich, that ships at sea might be located by the use of interrupted radio waves, but neither of these schemes was investigated and the whole subject was allowed to drop, presumably for lack of suitable techniques.

The principle of echo detection was, of course, well established, and was the basis of the " Asdic " detectors used in anti-submarine warfare. It is interesting to recall that at about this time a short-wave installation was fitted to the S.S. " Normandie " which gave an indication of the presence and rough bearing of neighbouring ships, but the essential measurement—that of range—still proved elusive.

However, by 1934 the German Air Force was growing at an alarming rate and considerable apprehension was being felt in this country about our lack of suitable methods of defence. This apprehension was not confined to our military advisers and there was a good deal of clamour in the National Press. There had been some vague talk, and still vaguer statements about the performance, of death-dealing rays as a means of combating air attacks which needed investigation, and in January 1935 Dr. H. E. Wimperis, then the Director of Scientific Research at the Air Ministry, asked Watson-Watt whether radio-destruction was even remotely possible. The discussion was quite informal, for the matter was very secret, but in a short time Watson-Watt, in collaboration with A. F. Wilkins, produced an answer. They showed that the amount of energy required to damage an aircraft engine or injure its crew was far too great to be produced by any known method and they added more or less as a postscript, the comment that "the difficult but much more promising problem of location by radio might be worth pursuing."

Watson-Watt was asked to elaborate this suggestion and on February 27, 1935 produced a 2,000 word specification of the requirements for an effective radar system based on the radio-echo method. Among other things he discussed the measurement of range, bearing and elevation, (i.e., location in the strict sense of the word) from a single station.

A demonstration was hurriedly arranged and a van containing suitable radio receivers was driven to within a few miles of Daventry. A pilot was instructed, without being told of the object of the flight, to fly on a prescribed course near the station when strong indications of the reflexion of waves from Daventry were observed.

In May of the same year a small team of scientists moved to an isolated site near Orfordness and, working on a wavelength of 50 metres, they demonstrated within a month that detection of aircraft up to 15 miles was possible utilizing the techniques they had developed for the pulse work in connexion with Sir Edward Appleton's work on the exploration of the ionosphere.

From then onwards the rest is history, a fascinating history of events leading to the magnetron, the thousand bomber raid on Cologne and the methods of dealing with submarines. Looking back at the perilous days through which we passed we are tempted to speculate on what might have happened had the postscript been shelved. " Never in the field of human conflict etc." may without hesitation be applied to Sir Robert Watson-Watt and his original team, and we should like to offer our congratulations to the recipients of these well merited awards.

At this period of national sorrow we should like to express our grief at the sudden passing of His Majesty King George VI, and to join with all our readers in offering our sympathy to the members of the Royal Family.

To our new Sovereign, Queen Elizabeth II, and to her husband, the Duke of Edinburgh, we send our loyal greetings with prayers for a long and peaceful reign.

God Save the Queen

The Theory and Design of Television Frame Output Stages

By Edward T. Emms,* B.Sc., A.R.C.S.

THE object of the frame output stage is to deliver to the frame deflector coils a current which changes substantially linearly with respect to time during the scan period. The deflector coils may be high impedance requiring a small peak-to-peak current to scan, or low impedance requiring a large peak-to-peak current to scan.

The output valve is rarely capable of delivering the current swing necessary to directly drive the frame deflector coils so that it is usual practice to employ a frame transformer.

If the transformer inductances (primary and secondary) are very large, the input current to the transformer is approximately sawtooth in form, this sawtooth current being obtained by an appropriate drive waveform on the grid of the output valve. This mode of operation has been favoured in the past.

However, if the peak valve current is limited (at a given anode voltage) more efficient modes of operation may be used by appropriately choosing the value of the transformer secondary inductance. By appropriate choice of this secondary inductance, the energy stored in the transformer shunt inductance may be made to contribute to the deflecting current at the commencement of scan. In particular, two modes may be distinguished:

(a) the Minimum Mean Anode Current (M.M.A.C.) condition;

(b) the Zero Initial Slope (Z.I.S.) condition.

It will be appreciated that these two modes are purely mathematical modes and that a design may yield operation approaching either (a) or (b) and still yield some advantages over the sawtooth drive condition previously mentioned. These modes of operation lead to anode current waveforms of the general form shown in Fig. 1. The load-lines on the $I_a - V_a$ characteristics take the forms shown in Fig. 2.

Fig. 3 gives a diagrammatic representation of some of the terminology used in this article.

NOMENCLATURE

L_p = inductance of transformer primary.
R_p = resistance of transformer primary.
L_s = inductance of transformer secondary.
r_s = resistance of transformer secondary.
L_y = inductance of deflector coils.
r_y = resistance of deflector coils.
$r_2 = r_s + r_y$
$L_2 = \frac{n^2 L_y}{k^2}\left\{1 + L_s(1 - k^2)/L_y\right\}$
k = coefficient of coupling $= M/\sqrt{L_p L_s}$
I_{pp} = peak-peak current required in deflector coils to scan
$x = k^2 L_2/n^2 r_2 T$
$y = k^2 L_p/n^2 r_2 T$
$\mu = y/x = L_p/L_2$
i_p = current in shunt primary.
$I_a(t)$ = output valve anode current.
I_a = mean output valve anode current.
T = trace time.
l = magnetic length of transformer core.
$I_{a\,min}$ = minimum output valve anode current.

General Analysis

For the purpose of a general analysis of the transformer circuit it is convenient to express the diagram in its equivalent form as shown in its equivalent form as shown

In this diagram L_p is the shunt inductance of the transformer; L_2 represents the sum of the leakage inductance $L_p(1 - k^2)/k^2$ and the deflector coil inductance transferred to the primary n^2L_y/k^2.

Thus:

$$L_2 = \frac{L_p(1 - k^2)}{k^2} + \frac{n^2 L_y}{k^2} = \frac{n^2 L_y}{k^2}\left\{1 + L_s(1 - k^2)/L_y\right\}$$

R_2 represents the total resistance of the secondary $(r_s + r_y)$ referred to the primary so that

$$R_2 = n^2(r_s + r_y)/k^2$$

We shall assume the deflector coil current to be linear during the scan period, having a peak-peak value I_{pp}. Thus referred to the primary we have

$$i_2(t) = \frac{kI_{pp}}{n}\left\{t/T - 1/2\right\} \quad \ldots\ldots (1)$$

We have two expressions for the voltage existing across the shunt inductance L_p namely

$$V_0(t) = L_p\, di_p/dt$$
$$= R_2 i_2 + L_2\, di_2/dt$$
$$= R_2 \frac{kI_{pp}}{n}\left\{t/T - 1/2 + x\right\} \quad \ldots\ldots (2)$$

where $x = L_2/R_2T$

Integrating expression (2) we obtain

$$i_p(t) = \frac{kI_{pp}}{2ny}\left\{(t/T)^2 - (1-2x)(t/T)\right\} + \frac{AkI_{pp}}{2n} \quad \ldots\ldots\ldots\ldots (3)$$

where A is a constant.

The output valve anode current I_a is the sum of i_p and i_2, so

$$\frac{I_a(t)}{kI_{pp}/2n} = (t/T)^2/\mu x + (t/T)\left\{2x(1+\mu) - 1\right\}/\mu x + (A - 1) \quad \ldots . (4)$$

where $\mu = y/x = L_p/L_2$.

It will be noted that in general the anode current waveform is parabolic in form.

Inserting the expressions for μ, x and y we find that

* *Mullard Research Laboratories.*

expression (4) may be written

$$\frac{I_a(t)}{kI_{pp}/2n} = \frac{r_2T}{k^2L_s}(t/T)^2 + \frac{r_2T}{k^2L_s}\left\{\frac{2L_s}{r_2T}(1+L_y/L_s)-1\right\} t/T) + (A-1) \quad \ldots\ldots\ldots\ldots (5)$$

We may first observe that if $k^2L_s/r_2T \gg 1$ the linear term in time will predominate and so if the secondary inductance is made sufficiently large the anode current waveform tends to become linear. Usually this means a comparatively uneconomic design. If we made the secondary inductance

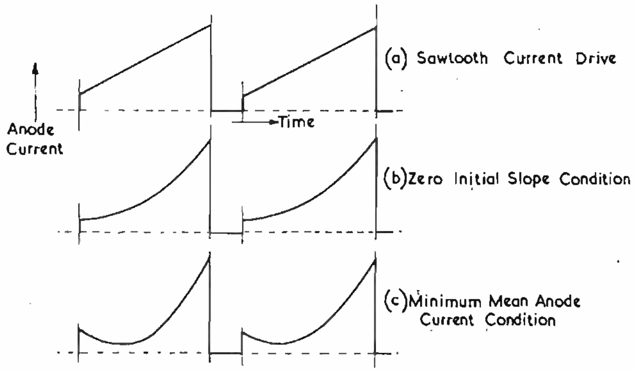


Fig. 1. The modes of operation

infinite (i.e., the transformer becomes an "ideal" transformer) the anode current would be truly linear and we should have

$$I_a(T) = I_a(0) + I_{pp}/kn \quad \ldots\ldots\ldots\ldots (6)$$

As the secondary inductance is reduced from infinity the parabolic term becomes more and more predominant. The minimum of the parabola which at high values of L_s is well to the left of $t = 0$ moves in towards $t = 0$ (Fig. 5). The actual position of the minimum may be found by differentiating Equation (5) with respect to t and equating dI_a/dt to zero. We find that the minimum of the parabola occurs at a time given by

$$t = -\left\{\frac{L_s + L_y}{r_2} - T/2\right\} \quad \ldots\ldots\ldots\ldots (7)$$

Thus if we reduce L_s until $L_s = r_2T/2 - L_y$ the minimum of the parabola then coincides with the start of scan. (Zero Initial Slope Condition). The minimum anode current then occurs at the start of scan (Fig. 5).

If the secondary inductance is reduced still further the minimum of the parabola moves to the right of the start of

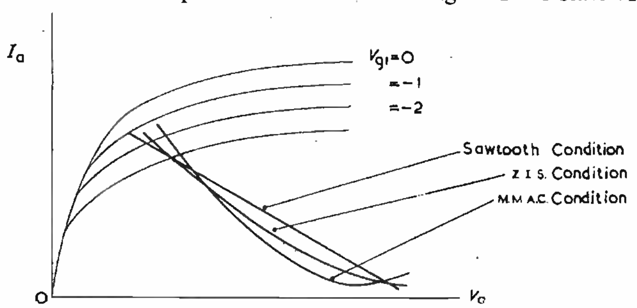


Fig. 2. Loadlines corresponding to the various modes

scan (Fig. 5). It will be shown later that with an appropriate choice of secondary inductance the average anode current may be minimized. (Minimum Mean Anode Current Condition).

The voltage V_1 across the primary terminals is given by

$$V_1(t) \doteq R_pI_a(t) + V_o(t) \quad \ldots\ldots\ldots\ldots (8)$$

Zero Initial Slope Condition

By appropriate choice of the transformer constants the anode current waveform may be made to have zero initial slope. As we have seen, the condition for this is

$$L_s = r_2T/2 - L_y \quad \ldots\ldots\ldots\ldots (9)$$

This equation implies that given the deflector coil inductance and the total secondary resistance, the secondary inductance of the transformer is fixed. This only leaves the transformer ratio to be fixed which may be done by consideration of the available peak anode current and the voltage to which the anode may be swung at time $t = T$.

In the case of Z.I.S.C. Equation (4) reduces to

$$\frac{I_a(t)}{kI_{pp}/2n} = 2(t/T)^2(1+L_y/L_s)/k^2 + (A-1) \quad \ldots (10)$$

The minimum anode current occurs at $t = 0$ so that

$$\frac{I_a(0)}{kI_{pp}/2n} = (A-1) \quad \ldots\ldots\ldots\ldots (11)$$

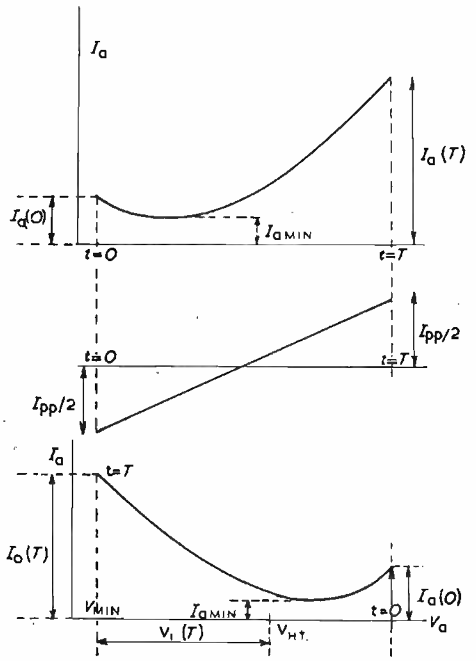
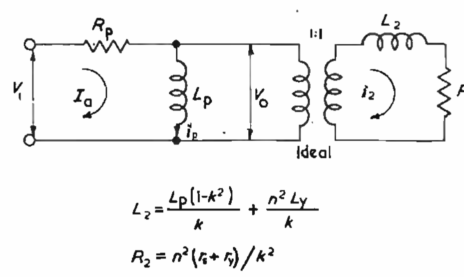


Fig. 3. Representation of nomenclature

Fig. 4. Equivalent transformer circuit



Combining Equations (10) and (11) we have

$$I_a(t) = I_a(0) + \frac{I_{pp}}{kn}(1 + L_y/L_s)(t/T)^2 \quad \ldots\ldots (12)$$

and in particular the anode current at the end of scan is given by

$$I_a(T) = I_a(0) + \frac{I_{pp}}{kn}(1+L_y/L_s) \quad \ldots\ldots\ldots (13)$$

The mean anode current during scan $\bar{I}_a$ may be found by integrating expression (12) between the limits $t = 0$ and $t = T$. We find

$$\bar{I}_a = I_a(0) + \frac{I_{pp}}{3kn}(1+L_y/L_s) \quad \ldots\ldots (14)$$

In the case where the minimum current $I_a(0)$ is very small it may be noted that the peak anode current is approximately three times the mean current.

The voltage waveform at the transformer input terminals is given by

$$V_1(t) = R_p I_a(t) + \frac{n r_2 I_{pp}}{k}\left\{ t/T - \frac{k^2}{2(1 + L_y/L_s)} \right\} \quad \ldots (15)$$

and in particular

$$V_1(0) = R_p I_a(0) - \frac{n k r_2 I_{pp}}{2(1 + L_y/L_s)} \quad \ldots\ldots\ldots\ldots (16)$$

and

$$V_1(T) = R_p I_a(T) + \frac{n r_2 I_{pp}}{k}\left\{ 1 - \frac{k^2}{2(1 + L_y/L_s)} \right\} \quad \ldots (17)$$

The anode wattage dissipation is given by

$$W_a = \frac{1}{T + T_r}\int_0^T I_a(t)\left\{ E - V_1(t) \right\} dt \quad \ldots (18)$$

$$\doteq \frac{T}{T + T_r}\left[\bar{I}_a \left\{ E + \frac{n r_2 k I_{pp}}{2(1 + L_y/L_s)} \right\} \ldots\ldots\ldots\ldots (19) \right.$$

$$\left. - R_p/5\left\{ 9\bar{I}_a^{2} + 4 I_a^2(0) - 8 I_a(0)\,\bar{I}_a \right\} - \frac{n r_2 I_{pp}}{4k}\left\{ 3\bar{I}_a - I_a(0) \right\} \right]$$

The preceding equations are sufficient to enable a complete design to be essayed. The procedure will be demonstrated in a later section.

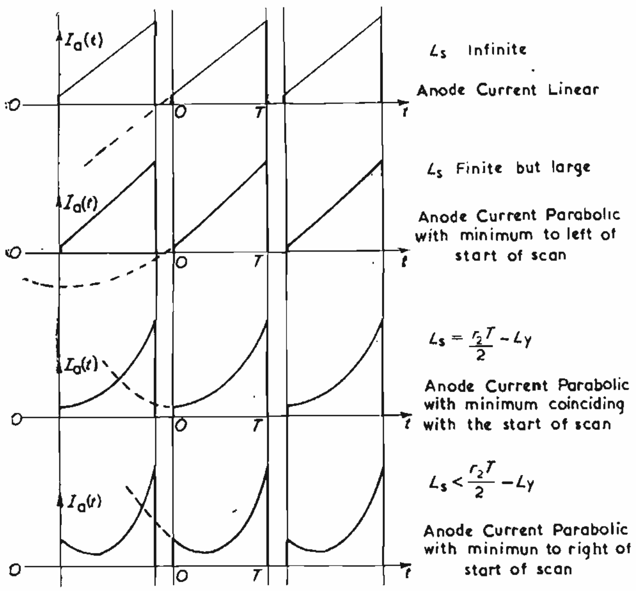


Fig. 5. Anode current waveforms

Minimum Mean Anode Current Condition

By appropriate choice of the transformer constants the mean anode current may be minimized. The minimum mean anode current condition occurs with the minimum of the anode current parabola to the right of $t = 0$ (Fig. 5). The position of the anode current minimum is given by

$$\frac{t}{T} = \frac{1}{2} - \frac{L_s}{r_2 T}\left(1 + L_y/L_s \right) \quad \ldots\ldots\ldots\ldots (20)$$

so that combining this equation with equation (5) gives as the minimum anode current

$$\frac{I_{a\,min}}{k I_{pp}/2n} = A - 1 - \frac{r_2 T}{4k^2 L_s}\left\{ 1 - 2L_s(1 + L_y/L_s)/r_2 T \right\}^2 \quad \ldots\ldots\ldots\ldots (21)$$

Thus combining equations (5) and (21) we find

$$\frac{I_a(t) - I_{a\,min}}{k I_{pp}/2n} = \frac{r_2 T}{k^2 L_s}\left[\frac{t}{T} - \frac{1}{2}\left\{ 1 - 2L_s(1 + L_y/L_s)/r_2 T \right\} \right]^2 \quad \ldots\ldots\ldots\ldots (22)$$

We may now integrate this expression between $t = 0$ and $t = T$ to find an expression for the mean anode current during scan.

$$\frac{\bar{I}_a - I_{a\,min}}{k I_{pp}/2n} = \frac{r_2 T}{k^2 L_s}\left[1/12 + L_s^2(1 + L_y/L_s)^2/r_2^2 T^2 \right] \quad \ldots\ldots\ldots\ldots (23)$$

Now we are in a position to differentiate $\bar{I}_a$ with respect to L_s to find the condition for minimum mean anode current. On putting $d\bar{I}_a/dL_s = 0$ we find the condition to be

$$L_s^2 = r_2^2 T^2/12 + L_y^2 \quad \ldots\ldots\ldots (24)$$

This equation implies that given the deflector coil inductance and the total secondary resistance, the secondary inductance of the transformer is fixed. This only leaves the transformer ratio to be fixed which may be done by consideration of the available peak anode current and the voltage to which the anode may be swung at time $t = T$.

In practice L_y is very much smaller than $r_2 T$ and the author prefers to use the condition

$$L_s = r_2 T/\sqrt{12} - L_y \quad \ldots\ldots\ldots (25)$$

which leads to far more attractive expressions for the peak current, mean current, etc. In all practical cases the condition expressed by (25) results in a practically identical design to that obtained when the condition expressed by (24) is used.

Employing the condition expressed in (25) we find

$$I_a(t) - I_{a\,min} = 1{\cdot}732\frac{I_{pp}}{kn}(1 + L_y/L_s)\left\{ t/T - 0{\cdot}211 \right\}^2 \quad \ldots\ldots\ldots\ldots (26)$$

We see that the minimum of the anode current parabola occurs about 21 per cent of the way through the scan.

In particular, at the start of scan we have:—

$$I_a(0) = I_{a\,min} + 0{\cdot}077\, I_{pp}\,(1 + L_y/L_s)/kn \quad \ldots\ldots\ldots\ldots (27)$$

while at the end of scan

$$I_a(T) = I_{a\,min} + 1{\cdot}077\, I_{pp}\,(1 + L_y/L_s)/kn \quad \ldots\ldots\ldots\ldots (28)$$

The mean anode current is given by

$$\bar{I}_a = I_{a\,min} + 0{\cdot}289\, I_{pp}\,(1 + L_y/L_s)/kn \quad \ldots\ldots\ldots\ldots (29)$$

Equations (28) and (29) yield the useful relationship

$$I_a(T) = 3{\cdot}73\,\bar{I}_a - 2{\cdot}73\, I_{a\,MIN} \quad \ldots\ldots\ldots (30)$$

while equations (27) and (29) give

$$I_a(0) = 0{\cdot}267\,\bar{I}_a + 0{\cdot}733\, I_{a\,MIN} \quad \ldots\ldots\ldots (31)$$

In the case where $I_{a\,min}$ is very small, i.e., the minimum anode current approximates to zero, Equations (30) and (31) give the rough rules.

(a) the average anode current is approximately 27 per cent of the peak current.

(b) the current at the start of scan is approximately 7 per cent of the peak current.

(c) the current at the start of scan is approximately 27 per cent of the mean current.

The voltage waveform at the transformer input terminals is given by

$$V_1(t) = R_p I_a(t) + n r_2 I_{pp}\left\{ t/T - \frac{0{\cdot}289\, k^2}{1 + L_y/L_s} - 0{\cdot}211 \right\} \Big/ k. \quad \ldots\ldots\ldots\ldots (32)$$

and in particular

$$V_1(0) = R_p I_a(0) - n r_2 I_{pp}\left\{ 0{\cdot}211 + \frac{0{\cdot}289\, k^2}{1 + L_y/L_s} \right\} \Big/ k \quad \ldots (33)$$

$$V_1(T) = R_p I_a(T) + n r_2 I_{pp} \left\{ 0{\cdot}789 - \frac{0{\cdot}289\, k^2}{1 + L_y/L_s} \right\} \Big/ k \quad \ldots\ldots (34)$$

The anode dissipation may be found by multiplying $I_a(t)$ by $(E - V_1(T))$, integrating with respect to t from $t=0$ to $t=T$ and then dividing the result by the total frame period. This procedure leads to an unwieldy result but if the assumption is made that the anode voltage swing during scan is linear with time, balanced about the H.T. line (which is well approximated in practice) we find:—

$$W_a = I_{a\,min}\left\{ E + 0{\cdot}089 V_1(T) \right\} + 0{\cdot}29\, I_{pp}\,(1 + L_y/L_s) \times \left\{ 2E - V_1(T) \right\} \Big/ kn \quad \ldots\ldots\ldots (35)$$

FRAME TRANSFORMER DESIGN CONSIDERATIONS

As have been seen, once the scanning coil inductance and the total resistance of the secondary are known, the inductance of the transformer secondary is specified by expression (9) or (25) depending on the mode of operation required. However, this implies that we must know the resistance of the secondary before we know its inductance! This difficulty may be overcome as follows:—

Suppose we wind n turns of wire in a given volume to have an inductance L and resistance r. Now suppose we wind $2n$ turns of wire of half the diameter. This will occupy approximately the same volume (unless the gauge is greater than 40 S.W.G. when the space factor drops away due to insulation) and both the resistance and inductance are quadrupled. Thus we may say that with the wire gauges commonly used to a very high degree of approximation the ratio of inductance to resistance of windings occupying the same volume on a given core (with a given gap) is constant. With this knowledge we may use our past experience to design the required secondary. Thus suppose we know from previous experience that with a given core (and gap) a 60mH coil may be wound having a resistance of 1·8 ohms; in general we may say that for any winding occupying the same winding space.

$$r_s = 1{\cdot}8/0{\cdot}06 \cdot L_s = 30 L_s$$

This expression may be used in conjunction with expression (9) or (25) to calculate both the secondary inductance and resistance. For example, suppose the resistance and inductance of the deflector coils are 7·5 ohms and 6·3mH respectively and that it is desired to operate in the zero Initial Slope Condition. Then from (9)

$$L_s + L_y = (r_s + r_y)T/2$$

and putting $T = 19$mS and using $r_s = 30L_s$ we have

$$L_s + 6{\cdot}3 \times 10^{-3} = (30L_s + 7{\cdot}5)\, 9{\cdot}5 \times 10^{-3}$$

whence

$$\begin{cases} L_s = 91\text{mH} \\ r_s = 2{\cdot}73\Omega \end{cases}$$

Thus using previous knowledge, a complete transformer secondary design may be achieved. Similarly, the transformer primary may be designed using the knowledge gained by previous experience. Examples of complete design procedures will be given in succeeding sections.

The final design must, of course, be checked to ensure that magnetic saturation of the core does not occur. Such saturation will lead to severe distortion which manifests itself as a severe non-linearity at the end of scan.

It is simple to show that the peak magnetizing field occurs at the end of scan and has a value

$$H_{max} = (4\pi N_s/10l)\left\{ n I_a(T) - k I_{pp}/2n \right\} \quad \ldots\ldots\ldots\ldots (36)$$

Using this value of peak magnetizing field, the peak flux density may be calculated for a given gap; consultation of the $B-H$ characteristic of the core material will indicate whether core saturation is being approached.

Finally the economic considerations of frame transformers must be considered. As a general rule it may be stated that the cost of a winding depends on the amount of copper used rather than the number of turns. The most economical gauges are those in the region of 30 S.W.G.

An Example of a Design in the Zero Initial Slope Condition

We shall take a deflector coil having inductance $L_y = 6{\cdot}3$mH, resistance $r_y = 7{\cdot}5\Omega$, and requiring 600mA peak-peak swing to scan. We shall assume the coefficient of coupling in the transformer to be 0·99. If from previous experience we know that we may wind a secondary having an inductance of 70mH and a resistance of 2·5Ω, on a given core (with a given gap) we have in general for a winding occupying the same volume $r_s = 36L_s$ so that substituting is expression (9) we obtain:—

$$L_s + L_y = (r_s + r_y)T/2 \quad \ldots\ldots\ldots\ldots (37)$$

whence

$$L_s = 98\text{mH}$$
$$r_s = 3{\cdot}52\Omega$$

Thus:

$$1 + L_y/L_s = 1{\cdot}064$$

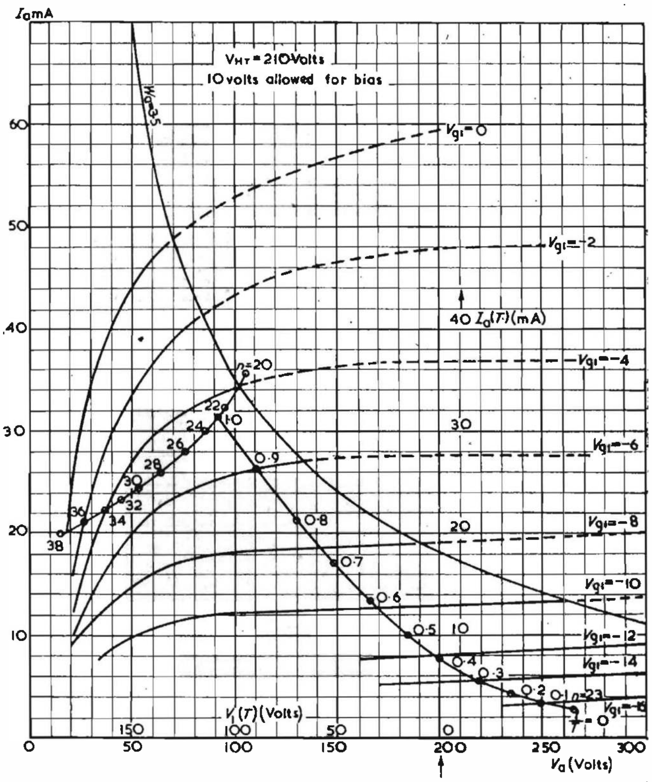


Fig. 6. Example of Z.I.S. design

If we take the minimum anode current as 3mA we have from expression (13)

$$I_a(T) = 3 + 648/n\,(\text{mA}) \quad \ldots\ldots\ldots\ldots (38)$$

The mean anode current is found to be (using expression (14)

$$\bar{I}_a = 3 + 216/n\,(\text{mA}) \quad \ldots\ldots\ldots\ldots (39)$$

The primary resistance may be estimated using previous knowledge. Thus, if in the remaining winding space (when the secondary has been wound) it is known that a winding may be constructed having an inductance of 33H, and a resistance of 650Ω, we have for windings occupying the same volume:

$$R_p = 650L_p/33 = 650n^2L_s/33 = 1{\cdot}93n^2(\text{ohms})$$

Thus expression (17) becomes

$$V_1(T) = 4{\cdot}85n + 5{\cdot}79 \times 10^{-3}\, n^2 \quad \ldots\ldots\ldots (40)$$

Using expressions (38), (39) and (40) the following table may be constructed.

n	L_p (Henries)	R_p (kΩ)	$I_a(T)$ (mA)	$\bar{I}_a$ (mA)	$V_1(T)$ (Volts)
20	39·2	0·723	35·4	13·8	99·3
22	47·4	0·935	32·5	12·9	109·6
24	56.5	1·11	30·0	12·0	119·5
26	66·2	1·30	27·9	11·3	129·9
28	76.8	1·52	26·1	10·7	140·3
30	88·3	1·74	24·6	10·2	150·7
32	100	1·93	23.3	9·7	161·1
34	113	2·23	22·1	9·3	171·5
36	127	2·50	21·0	9·0	182·0
38	142	2·79	20·1	8·7	192·6

It is convenient to plot I_a (T) against V_1 (T) the latter coordinates reading from right to left. If this graph is plotted on transparent paper it may be moved across the $I_a - V_a$ characteristic of the output valve and the best ratio chosen from the point of view of

(a) not exceeding the peak current available from a low limit valve at the end of life.

(b) not entering the knee region and causing non-linearity at the end of scan.

(c) cheapness of transformer compatible with (a) and (b).

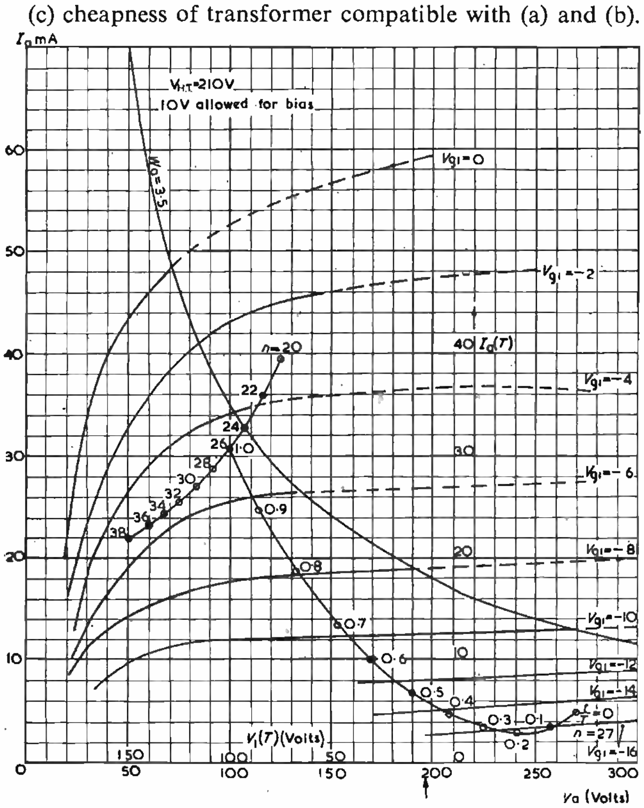


Fig. 7. Example of M.M.A.C. design

This procedure is illustrated in Fig. 6. A transformer ratio of 23:1 appears reasonable. Larger ratios have their terminal points of the load line entering the knee region while smaller ratios lead to higher peak currents. With the 23·1 ratio the peak current required is 31mA and occurs (with $V_{H.T.}$ = 200 volts) at V_a = 88 volts. The load line for the 23:1 ratio transformer has been constructed in Fig. 6.

It remains to check that the core does not saturate and that the anode dissipation is not exceeded. The peak magnetizing field may be calculated using expression (36).

$$H_{MAX} = 0{\cdot}736\ N_s/l \text{ Oersteds.}$$

so that if the number of secondary turns is known H is known, and B_{MAX} may be calculated. It remains to check this figure against the B-H curves of the core material to ensure saturation is not approached.

The anode dissipation may be calculated using expression (6). In the example illustrated in Fig. 6 since the load line always lies within the W_a = 3·5 watts limit it is clear that the anode dissipation rating is not exceeded.

An Example of a Design in the Minimum Mean Anode Current Condition

We shall take a deflector coil having inductance L_y = 6·3mH resistance r_y = 7·5Ω, and requiring 600mA peak-peak swing to scan. We shall assume the coefficient of coupling of the transformer to be 0·99. If from previous experience we know that we may wind a secondary having an inductance of 70mH and a resistance of 2·5Ω on a given core (with a given gap) we have in general for a winding occupying the same volume r_s = 36 L_s so that substituting in expression (25) we obtain:

$$L_s + L_y = (r_s + r_y)T/\sqrt{12} \quad \ldots\ldots\ldots (41)$$

whence

$$L_s = 56{\cdot}8\text{mH}$$
$$r_s = 1{\cdot}7\Omega$$

Thus $1 + L_y/L_s$ = 1·111.

If we take the minimum anode current as 3mA we have from expression (28)

$$I_a(T) = 3 + 724/n \text{ (mA)} \quad \ldots\ldots\ldots (42)$$

The mean anode current is found to be (using expression (29)

$$\bar{I}_a = 3 + 193/n \text{ (mA)} \quad \ldots\ldots\ldots (43)$$

The primary resistance may be estimated using previous knowledge. Thus, if in the remaining winding space (when the secondary has been wound) it is known that a winding may be constructed having an inductance of 33 Henries, and a resistance of 650 ohms, we have for windings occupying the same volume.

$$R_p = 650\ L_p/33 = 650n^2L_s/33 = 1{\cdot}93n^2 \text{ (ohms)}$$

Thus expression (34) becomes

$$V_1(T) = 3{\cdot}79n + 3{\cdot}36 \times 10^{-3}\ n^2 \quad \ldots\ldots (44)$$

Using expressions (42) (43) and (44) the following table may be constructed.

n	L_p (Henries)	R_p (kΩ)	$I_a(T)$ (mA)	$\bar{I}_a$ (mA)	$V_1(T)$ (Volts)
20	22.8	0·448	39·2	12·7	77·1
22	27·5	0·543	35·9	11·8	84·9
24	32·8	0·646	33·2	11·0	92·9
26	38·4	0·757	30·9	10·4	100·9
28	44·6	0·878	28·8	9·9	108·6
30	51·2	1·02	27·1	9·4	116·7
32	58·3	1·15	25·6	9·0	124·6
34	65·7	1·30	24·3	8·7	132·6
36	73·7	1·45	23·1	8·4	140·6
38	82·2	1·62	22·0	8·1	148·9

It is convenient to plot $I_a(T)$ against $V_1(T)$ the latter coordinates reading from right to left. If this graph is plotted on transparent paper it may be moved across the I_a − V_a characteristic and the best ratio chosen from the point of view of

(a) not exceeding the peak current available from a low limit valve at the end of life.

(b) not entering the knee region and causing non-linearity at the end of scan,

(c) cheapness of transformer compatible with (a) and (b).

This procedure is illustrated in Fig. 7. A transformer ratio of 26:1 appears reasonable. Larger ratios have the terminal points of their load lines entering the knee region while smaller ratios lead to higher peak currents. With the 26:1 ratio the peak current required is 31mA and occurs (with $V_{H.T.}$ = 200 volts) at V_a = 98 volts. The load line for the 26:1 ratio transformer has been constructed in Fig. 7.

It remains to check that the core does not saturate and the anode dissipation rating is not exceeded. The peak magnetizing field may be calculated using expression 5.1.

$$H_{MAX.} = 0{\cdot}997 N_s / l \text{ Oersteds}$$

so that if the number of secondary turns is known $H_{MAX.}$ is known and $B_{MAX.}$ may be calculated. It remains to check this figure against the *B-H* curves of the core material to ensure saturation is not approached.

The anode dissipation may be calculated using expression (35). In the example illustrated in Fig. 7 since the load line always lies within the $W_a = 3{\cdot}5$ watts limit it is clear that the anode dissipation rating is not exceeded.

A Comparison of the Zero Initial Slope Condition and the Minimum Mean Anode Current Condition

Such a comparison is best carried out using the results previously obtained. If we choose designs to have a peak current of 35·5mA we have

	n	L_p (Henries)	L_s (mH)	$\overline{I_a}$ (mA)	$V_1(T)$ (Volts)
M.M.A.C. Condition	22	27·5	56·8	11·8	84·9
Z.I.S. Condition ..	20	39·2	98·0	13·8	95·3

while if a peak anode current of 24.4mA is chosen we have

M.M.A.C. Condition	34	65·7	56·8	8·7	132·6
Z.I.S. Condition ..	30	83·3	98·0	10·2	144·7

It will be seen that the Zero Initial Slope Condition leads to

(a) larger transformer inductances

(b) larger mean anode current

(c) larger voltage swing

compared with a Minimum Mean Anode Current having the same peak anode current. These points will be examined in turn.

(a) The designs have been made such that in all cases the same winding volume is assumed. However, it may be noted that the peak magnetizing field will be the same and so the only point to be considered in the comparison is the ease of winding. Clearly if the primary inductance is very high, to enclose it within the available space will necessitate a fine gauge. If perchance the wire gauge exceeds 40 S.W.G. the space-factor falls away and so in this case the Z.I.S. condition will result in a less satisfactory solution than the M.M.A.C. condition.

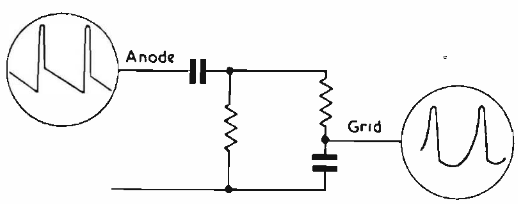


Fig. 8. The feedback network

(b) In general the limitation which settles the design is the usually available peak anode current. However, the smaller the mean anode current the smaller the anode dissipation, so that in the case where anode dissipation is a limitation the M.M.A.C. condition is superior.

(c) The larger voltage swing exhibited by the Z.I.S. condition implies that in this design the peak current must be available at a lower anode voltage. This point may provide a limitation, but in general the increase in voltage swing over the corresponding M.M.A.C. condition is rarely serious.

As against these disadvantages of the Z.I.S. condition compared with the M.M.A.C. condition it must be noted that the required drive waveform to the output valve is much more easily obtained in the case of the Z.I.S. condition.

The Feedback Network

It has been seen that if operation in the Z.I.S. condition or the M.M.A.C. condition is required the anode current must contain a parabolic component. In the case of the Z.I.S. condition the origin of this parabola should occur at the commencement of scan, while for the M.M.A.C. condition the minimum of the parabolic component should occur at approximately 21 per cent of the way through the

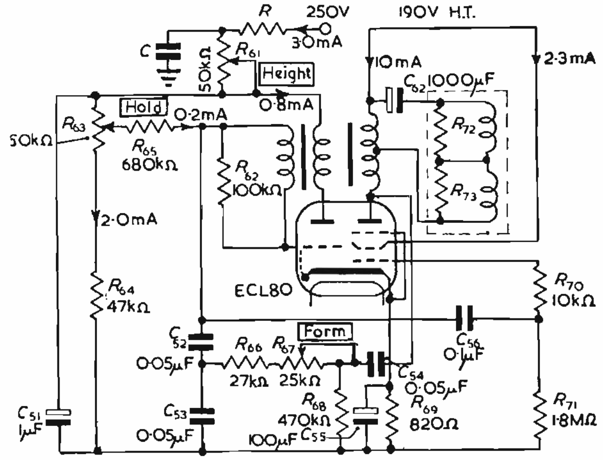


Fig. 9. Circuit of frame time-base

scan. The grid drive to the output valve must be such that the desired parabolic anode current waveform is obtained. This parabolic component is most conveniently obtained by a network attached to the output valve anode and added to the exponential waveform provided by the scanning generator.

The waveform obtaining at the anode of the output pentode falls approximately linearly during the scan period and then consists of a positive-going pulse (approximately a half-sinusoid) during flyback. The desired parabolic component may be obtained by connecting the network shown in Fig. 8 to the anode and connecting the output terminals to the grid circuit of the output valve. A practical arrangement is shown in Fig. 9. A detailed analysis of this network is not to be recommended since the non-linearity of the $I_a - V_g$ characteristic of the valve must be taken into account in such an analysis. A practical determination of the components to be used is far quicker, and more revealing.

Such a negative feedback system in frame-base output stages is of very great importance insofar as the effects of hum and microphony are both reduced enormously. The usual type of frame output valve is usually akin to the type used for sound output (in fact usually the same type of valve serves both purposes in a television receiver). Although care is exercised in producing sound output valves in which the hum level and microphony are negligible when the valve is used in a conventional audio output stage, such valves may give rise to considerable trouble if used in the frame output stage. This follows primarily since the eye is capable of detecting hum modulation and microphonic disturbance in the picture long before the ear could detect such components in the audio stage. Thus it is highly desirable always to employ negative feedback in frame output stages.

Acknowledgments

Acknowledgments are due to Mullard Ltd. and to Dr. C. F. Bareford, Manager of Mullard Research Laboratory, for encouragement in this work and permission to publish the article.

A Heart-Rate Recorder
for Biological Experiments

By W. E. Boyd,* M.A., M.D., M.Brit.I.R.E. and W. R. Eadie*

An electronic heart-rate recorder is described for use on decerebrated or anaesthetized animals. The rate is shown as a continuous graph on a recording milliameter and can be based at will on the auricular or ventricular action potentials. Wide variations in the shape of the E.C.G. *do not introduce error. The range of* 10 *to* 60 *beats per minute can be readily extended.*

SEVERAL workers[1,2,3] have described instruments for the production of a continuous record of the rate of the human heart. Broadly speaking these operate on a common principle. The electrical output of the heart, which when recorded is termed the electrocardiogram or E.C.G., is suitably amplified and triggers a circuit which produces, for each heart-beat, an impulse of constant amplitude and duration. On integration these give a deflexion on a meter proportional to the rate of the heart.

Early attempts in these laboratories to make use of similar instruments for recording the rate of a frog heart, during tests on drug action for instance, showed them to

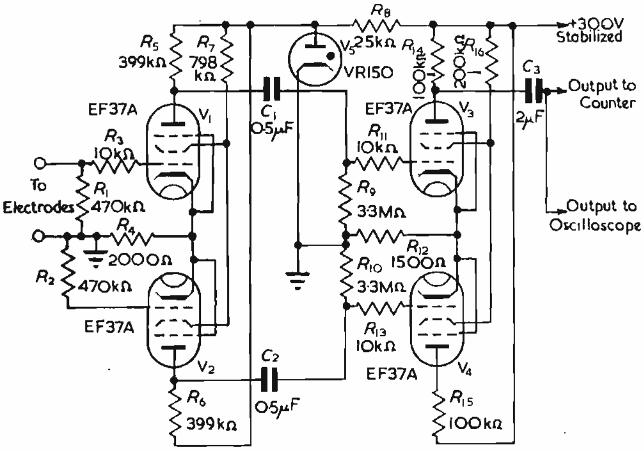


Fig. 1. Two-stage pre-amplifier

possess many disadvantages for this work. The main faults were:—

(1) Changes in waveform of the E.C.G. throughout the course of a test frequently caused the triggering circuit to miss beats or to operate more than once on each beat.

(2) When the amplitude of the background interference became comparable with that of the E.C.G. (circumstances which occurred all too frequently), there was a tendency to trigger on peaks of the interference as well as on the heart impulse. This condition was aggravated by the amount of 50c/s interference induced when the operator touched or even approached the frog to apply drugs.

(3) No distinction could be made between the rate based on the auricular beat as denoted by the P-wave (see inset in Fig. 2) and one based on the ventricular beat as denoted by the R-wave. Cases of A-V heart block could not therefore be distinguished.

(4) In some designs no provision was made to remove the "heart rhythm" from the recording meter. This was particularly troublesome at low rates and caused the meter to give a broad band on the record instead of a line.

The instrument to be described was developed to overcome these defects as far as possible and to have an accuracy, excluding the ink-writer error, of better than 1 per cent over long periods. Although primarily designed for use in research on the action of drugs on frog hearts, little modification is required to make it equally suitable for recording the speed of various types of mechanism. It can, moreover, be used for the human heart, but if much serious work in this field is contemplated it will be found preferable to adopt a more elaborate design incorporating additional features which permit greater freedom of the subject and a wider choice of electrode positions. This will be described in a later paper. The present design is therefore most suitable for anæsthetized or decerebrated animals.

Method of Operation

The heart potentials received from the subject by the electrodes are amplified and passed to a frequency selector stage giving a damped oscillatory wave output. A selected portion of this triggers two univibrators in cascade. The output of the second univibrator is integrated and the voltage developed controls a valve-voltmeter, which operates a recording milliameter.

Apparatus

For convenience in construction and maintenance the equipment has been divided into seven units.

(1) Pre-amplifier.
(2) Cathode-ray oscilloscope and camera.
(3) Frequency selector and clipper.
(4) Pulse shaper and delay circuit.
(5) Valve-voltmeter and monitor speaker amplifier.
(6) Calibrator.
(7) Stabilized power supply.

Pre-amplifier

The average peak voltage to be expected from a frog heart under the special conditions of this research was in the region of 0·3mV to 1·0mV. The pre-amplifier had therefore to be sufficiently free from self generated noise to keep the background well below the amplitude of the smallest part of the wave likely to be used. The P-wave may, for example, be as low as 50μV peak. As it was also experimentally necessary to record simultaneously the E.C.G. without visible distortion, it was convenient to employ the same pre-amplifier for both purposes. A much lower standard of performance, particularly in frequency response, would otherwise have been permissible.

In early experiments a two-stage single ended amplifier was used with both H.T. and L.T. supplied from batteries. The inconvenience of maintenance, however, and the uncertainty of stage gain due to falling battery voltages led to the adoption of the all-mains version shown in Fig. 1.

To reduce interference it would have been preferable to

* *The Boyd Medical Research Trust, Glasgow.*

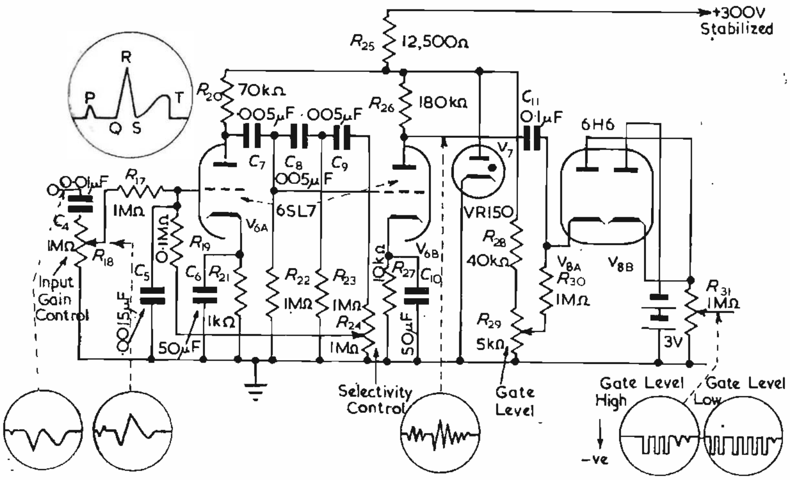


Fig. 2. Frequency selector and clipper stages

The large inset shows a typical frog E.C.G. with the standard method of designating the respective parts. (It should be noted that in this inset upwards represents a negative potential as is conventional in electro-cardiography while in the small insets showing the wave-form at various points upwards represents a positive potential.)

use a balanced input with a long-tailed pair, but the idea had to be discarded as it was found that unless one electrode was maintained at earth potential any attempt to apply drugs produced large disturbances in the amplifier. With the single ended input 50c/s interference was very marked. This was overcome by enclosing the frog in an earthed cage with an open front, sufficiently large to permit of easy manipulation. The design of the amplifier follows standard practice at these frequencies, the required performance being achieved without difficulty. The response is sensibly flat from 0·3c/s to 100c/s with a measured overall gain of 9,400. Total noise level is under 15μV and is therefore below both the resolution of the cathode-ray tube trace (1cm for 0·5mV input) and any P-wave likely to be encountered. The heaters are supplied from a separate 6V winding with the customary " humdinger."

Cathode-ray Oscilloscope and Camera

The oscilloscope was originally installed to enable the E.C.G. to be photographed. It has, however, been found a very convenient aid in setting up the heart-rate recorder. In cases of A-V heart block, for example, one part of the heart can beat at a different rate from the other, i.e., a rate based on the P-wave could differ from one based on the R-wave. One must therefore know whether the recorder is triggering on the P-wave or the R-wave, or even that it is actually the heart potential and not some spurious signal which is actuating it.

To this end Z-axis modulation was tried using the output of one of the univibrators. This gave a bright spot on the E.C.G. at the point where the univibrator triggered. The system, however, did not find such favour with the biological staff as did a loudspeaker actuated from the same source. The latter method was therefore adopted as it has the additional advantage that the operation of the instrument can be monitored continuously while other work is in progress. Where the oscilloscope is not required an electron tuning indicator combined with a loudspeaker would serve equally well.

The oscilloscope used is a Cossor model 339 double beam. The internal amplifier of this model was never intended for E.C.G. work and is quite unsuitable. It was therefore converted to a single stage balanced type and the general performance is now comparable with that of the pre-amplifier. The second beam is available for other data, such as the mechanical pull of the heart and is fed from a separate external amplifier.

Frequency Selector and Clipper

As already stated, two of the major problems were to keep the P-wave above the general noise level and to differentiate continuously between the P-wave and the R-wave in triggering of the univibrator. The overall noise originates from three main sources.

(a) Normal amplifier noise such as thermal, flicker and partition noise and mains ripple from the heater and H.T. supply.

(b) Noise originating within the specimen, such as nerve, muscle and electro-chemical potentials.

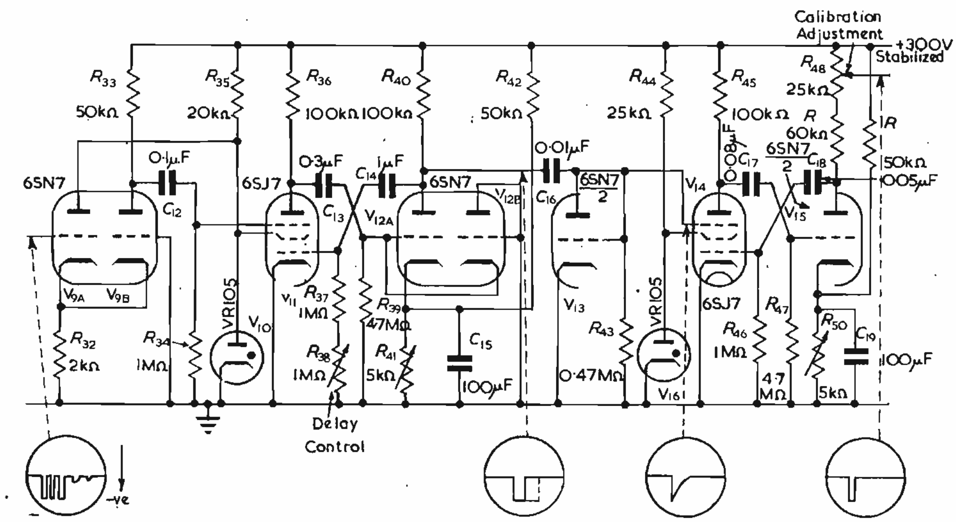
(c) Spurious potentials induced in the specimen and the connecting leads, such as 50c/s interference, from nearby wiring or via the operator.

Unless care is exercised this background can assume considerable proportions.

The obvious plan was to adjust the level of a " gate " circuit to accept above some particular voltage. In some cases this did work quite well, but in all too many frogs it was found that either the P-wave was lost in the background noise or the voltage difference between the P- and R- and even the T-waves was much too small for reliable differentiation between them over a period. An added complication was the tremendous variations which can take place in the shape of the E.C.G. in a matter of minutes during certain experiments.

Many ideas were tried, but it was not until a frequency analysis was made of the E.C.G. of a number of frogs that a solution presented itself. It was found that the harmonic content of the R-wave around 15c/s was, in the majority of cases, much larger than that of the P-wave, while that of the T-wave was, in comparison, generally negligible. Moreover, this difference appeared to hold at this frequency, for wide variations in the shape of the E.C.G. A selective stage, resonating at 15c/s was therefore included in the amplifier chain. As a result it is seldom that a work-

Fig. 3. Pulse shaping and delay stages



able difference cannot be maintained between the P- and R-waves. In addition, P-waves which hitherto have been too small to be used for triggering can now be raised sufficiently far above the background noise.

A variety of circuits were available for this selective stage, but there seemed no point in choosing anything more complex than the single-valve phase-shift type (see V_{6A} Fig. 2). It is essential to avoid overloading in this stage by keeping the input down and not adjusting to a higher gain than is necessary. Overloading will produce a limiting action which may bring us back to where we started. The pre-set potentiometer R_{24} controls the amount of feedback. The best method of setting up the stage has been found to be that of connecting an oscilloscope to the anode of V_{6B} and adjusting R_{24} until a waveshape similar

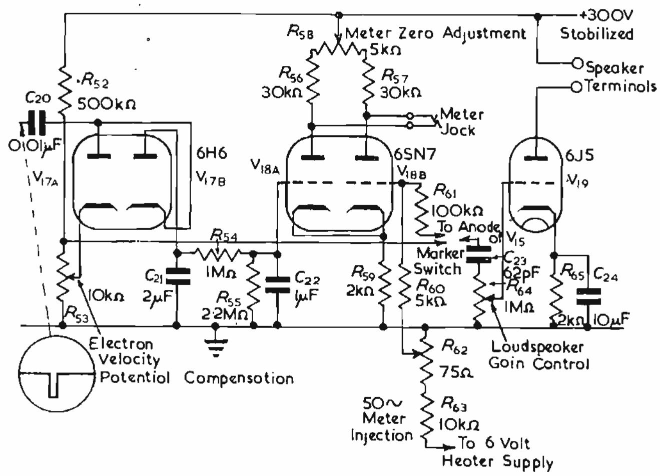
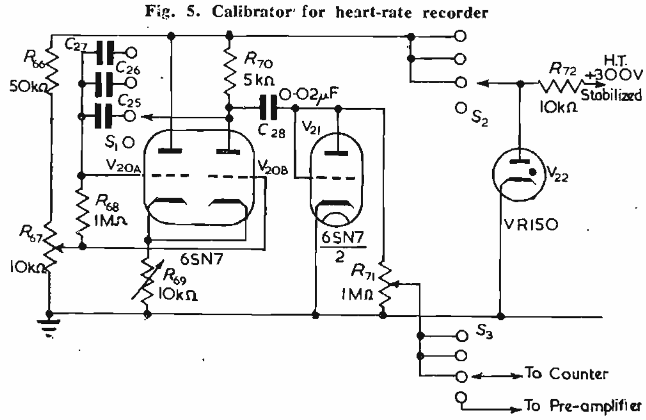


Fig. 4. Valve voltmeter and loudspeaker amplifier

Fig. 5. Calibrator for heart-rate recorder



to that shown in the inset is obtained from the normal E.C.G. The adjustment is not critical and can usually be locked in position.

The gate consists of a series diode V_{8A} with a positive bias on the cathode adjustable by R_{29}. The point at which V_{8A} starts to conduct can thus be set to include or reject the P-wave. The univibrator will trigger on the first signal of each group received, so by setting the height of the gate we can trigger it on either the P-wave or the R-wave.

Since the amplitude of the R-wave might be sufficiently large to cause undesirable surges in the succeeding stages it is clipped by the diode V_{8B}. The signal passed to V_9 (Fig. 5) is thus of constant amplitude.

It will be observed that the time-constant of the input circuit C_4R_{17} is kept small. This was found essential, as very low frequency potentials from the frog, of electrochemical or other origin tended to block V_{8A} with a consequent artefact on the recorded trace.

In the small insets (Fig. 2) showing the waveform at each point, it will be noted that the E.C.G. is the reverse of the normally accepted convention in electrocardiography, wherein a negative potential is shown upwards. This was done to avoid confusion with the remaining waveforms which adhere to the normally accepted convention of upwards being positive.

Pulse Shaping and Delay

The theory of the counting ratemeter, as used for example in nuclear physics, is now well known.[4] An important point, however, is that the duration of the impulse passed to the integrating circuit must be very much shorter than the time interval between each impulse.

If now we examine the waveform of the output of V_8 (Fig. 2) we find that it consists of a slice of a damped oscillatory wave and is in effect a series of short duration square waves. If we applied these impulses to a univibrator having a time cycle sufficiently short to meet the above requirement, it would trigger on each of these square impulses. It was therefore necessary to interpose some form of delayed circuit which, on being opened by the first impulse, would remain open throughout the remainder of the heart-beat.

The choice of a suitable circuit for this stage was found to be more difficult than at first appeared. The main criteria were that the delay period should be adjustable and constant, irrespective of succeeding impulses and that re-initiation be possible immediately on the completion of

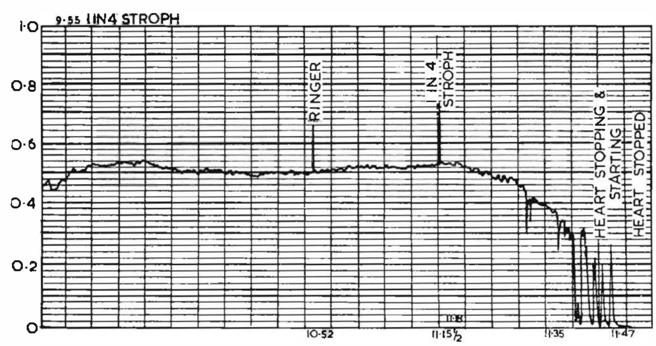


Fig. 6. Two-hour section of a typical heart-rate record

This shows how a 1 in 4 dilution of Strophanthus has stopped the heart action. The vertical lines represent 5 minute intervals while each horizontal line represents two beats per minute.

each cycle. The univibrator held out the most promise and of the many variations tried, that shown was by far the best. The use of the suppressor grid for the triggering impulse (V_{11}) is due to Puckle[5] and the early re-initiation diode (V_{12B}) to Allan.[6]

Since the length of the delay period in use, as set by R_{38} governs the maximum rate which can be recorded it should be adjusted to cover only that part of the waveform which threatens to cause premature triggering. Higher rates of count can be obtained by reducing C_{14}.

The phase reversal stage V_{9A} is inserted to provide V_{11} with the required negative triggering impulse.

Valve-Voltmeter and Monitor Speaker Amplifier

In recorders for the low rates we are considering, one of the problems is to eliminate from the meter the surges of "heart rhythm" produced in the integrating circuit by the arrival of each impulse. The time interval between each is sufficiently long for the meter to follow and the recorded graph becomes a broad band instead of a line.

A number of solutions are available, such as that due to F. Henry.[2] In this a balanced valve-voltmeter as in $V_{18}A$ and V_{18B} (Fig. 4) has the two grids coupled together by a large capacitor (not shown). The surge voltage is thus fed in phase to the two valves and cancels out in the meter. The D.C. component on the other hand affects only the grid of the first valve and so registers on the meter. Although the method is simple and effective it was not incorporated in the design as it was desirable to make use of the grid of V_{18B} for another purpose.

In conducting drug tests, it is essential to record on the graph the exact moment when the drug is applied. By means of a switch held in the operator's hand the contacts shown as "Marker Switch" (Fig. 4) are closed at the correct moment and produce a deflexion of the meter. The time-constant of this grid circuit (V_{18B}) being low, the recording meter returns to its original position immediately, so giving a thin transverse line on the graph. In the grid circuit of V_{18A} on the other hand the presence of the integrating capacitor C_{21} causes the meter to return in an exponential curve. The "marker signal" is therefore distinctive and cannot be confused with anything else appearing on the graph. It follows, however, that we cannot use any system of eliminating the surge which will materially increase the time-constant of the grid circuit of V_{18B}. The method finally adopted is the simple one of filtering out the surge by means of R_{54} and C_{22}. It has, of course, the disadvantage that although the beginning of a change is always shown immediately, the larger the time-constant of the filter the longer it will take for the meter to show the full extent of any change in rate. The values chosen are a compromise suited to the work for which the design was intended. For abrupt changes in rate and including lag caused by the pen of the recorder, the indicated rate shows 95 per cent of the true value in 30 seconds. Use has also been made of the grid of V_{18B} to introduce a small amount of 50c/s from the heater supply to reduce pen to paper friction.[7]

The monitor speaker and its amplifier require no comment. Reference has already been made to their use.

Calibrator

It is a great advantage in equipment of this nature to have a self contained means of checking the calibration. This is provided by the circuit of Fig. 5, wherein any one of three frequencies between 20 and 60 per minute is available. The double triode V_{20A} and V_{20B} produces a square wave of frequency governed by C_{25} to C_{27}.[8] By differentiating it through C_{28} and suppressing the positive peak by V_{21} we have a spiked waveform not unlike the QRS of the electrocardiogram. The long-term stability of the calibrator has been found to be surprisingly good (within one beat per minute over several months) but in any case the rate is sufficiently low to check with a stop-watch if required.

Stabilized Power Supply

The power supply is a conventional series-valve stabilized type providing 85mA at 300V. In view of severe mains fluctuations preference has been given in the design to reducing these rather than to low internal impedance.

A constant voltage transformer provides heater current for all valves.

The indicating meter in use is an Evershed and Vignoles 0-1mA recording milliameter run normally at a paper speed of 3in. per hour.

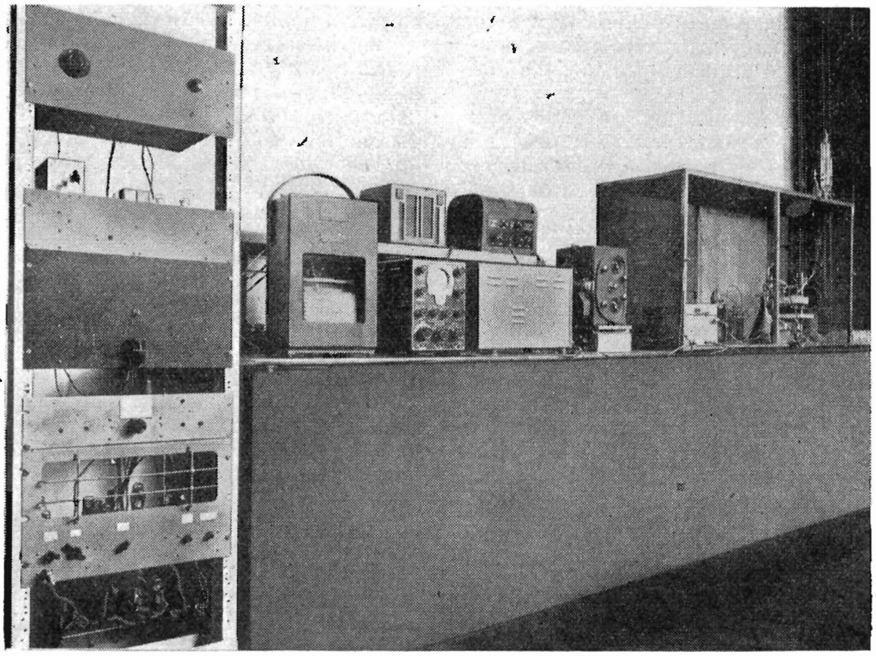


Fig. 7. General view of the heart-rate recorder in use

The screening cage housing the frog and the pre-amplifier can be seen on the right. The two lower panels in the rack on the left house the other stages. The remaining panels contain amplifiers and power supplies for displaying information concerning the mechanical action of the frog heart.

A two hour section of the record of a frog heart is shown in Fig. 6, while Fig. 7 gives the experimental layout of the complete apparatus.

Acknowledgments

Our thanks are due to the Trustees of the Boyd Medical Research Trust, to the Management of the Glas. Hom. Hospital and to the Western Regional Board for support in this research, also to Dr. E. Fairley of the Electrical Engineering Dept., Royal Technical College, Glasgow for helpful criticism in the preparation of this paper which was first submitted for publication in July, 1951.

REFERENCES

1 HORTON, J. W.: An Electronic Cardiotachometer, *Electronics*, Aug. (1938).
2 HENRY, F.: Direct Reading Cardiochronoscope, *J. Exper. Psychol.*, *22*, 598-601 (1938).
3 STRUM and WOOD: Instantaneous Recording Cardiotachometer, *Rev. Sci. Instr.*, *18*, 771 (1947).
4 ELMORE, W. C., and SANDS, U. L.: Electronics: Experimental Techniques, p 250 (McGraw-Hill, New York).
5 PUCKLE, O. S.: Time Bases (Chapman & Hall, Ltd., London).
6 ALLEN, A.: Research Department, A. C. Cossor, Ltd., London.
7 TUCKER, U. J.: The Effect of Pen-to-Paper Friction in Recording Instruments, *Elec. Eng.*, *23*, 61-63 (1951).

Proposed Test Procedure for F.M. Broadcast Receivers

By D. Maurice,* Ing.E.S.E., A.M.I.E.E., G. F. Newell* and J. G. Spencer*

IN connexion with the high-power tests, using both amplitude modulation and frequency modulation, that are being made with the B.B.C. V.H.F. transmitter at Wrotham, it has been found desirable to decide on a standardized procedure for testing F.M. receivers. Should it be decided that F.M. is to be employed in the future for nation-wide sound broadcasting, it will be important to be able to compare the performance of different receivers. A further reason for attempting to detail methods of test at this early stage is the necessity of discovering the limitations of existing test equipment and the requirements which such equipment as may be developed in the future should fulfil.

The present article describes a procedure that has been found convenient for testing F.M. receivers; it does not attempt to specify what their performance ought to be, but gives, by way of illustration, results obtained on three actual receivers.

The novel instruments required for the tests are described and the test conditions and parameters are detailed. Test procedure is dealt with and as examples the test results on three receivers are given.

The test conditions and parameters and the procedure described were finally decided upon only after careful study of the Interservice Radio and Electronic Measurements Committee document "Interservice Standard Definitions of Radio-Receiver Characteristics" and the Institution of Radio Engineers "Standards on Radio Receivers, Methods of Testing Frequency-Modulation Broadcast Receivers".

Examination of the test equipment and procedures described hereafter will reveal many departures from what may be described as normal medium-wave broadcast receiver measurement practice. While many of these departures are necessitated by V.H.F. F.M. conditions, some are not, and are put forward for consideration now because they seem better adapted to the purpose of performance (as against "designer" type) testing than some methods used hitherto.

The purposes of testing the performance of broadcast receivers include the measurement in objective terms of the subjective assessment which would be given in words by a listener, or the attempt to allocate numbers to the subjective criteria (descriptive words) which the listener would use. Another purpose is to compare receivers between which the subjective performance differences are not very great. Yet another reason lies in considerations of design for which it is desirable to correlate the objective effects of certain methods or circuits adopted by the designer. The tests described hereafter are not intended to include the last reason given, unless this object is achieved fortuitously.

A first example of departure from previous practice is that of the output power noise meter which, it is suggested, should really measure either mean-square voltages or root-mean-square voltages. The reason for this is that it has been found[1] that R.M.S. voltage is a satisfactory parameter of electrical noise of either the random fluctuation or impulsive types in that the annoyance caused by them is closely approximated by their R.M.S. values. An aural weighting network was found to be desirable when measuring noise[1] and the one giving rise to the curve in Fig. 1 was chosen.

A second example is the adoption of 40 per cent rather than 30 per cent modulation for standard modulation depth. This is merely because it is thought that 40 per cent is nearer to average programme modulation depth than is 30 per cent.

It may be asked why, if the aural weighting curve is adopted for noise measurement, it has not been suggested for the measurement of distortion. The reason is simply that the weighting network has been tried and found satisfactory for noise measurement, but so far no experiments have been undertaken with it with regard to distortion, and in the absence of practical evidence it would not be permissible to put it forward.

The choice of 2kc/s as the standard modulation frequency is because this is near the frequency at which the curve in Fig. 1 presents a maximum and thus variations in response due to errors in modulating frequency will be minimized.

The choice of 40db as the standard ratio of signal to unwanted response (noise or interference) is because this ratio corresponds very roughly to a "slightly disturbing" level of undesired response.

The choice of total R.M.S. distortion, unweighted, as being a measure of the subjective effect of non-linearity is admittedly a poor one, but until more work has been published on the subjective effect of distortion it was thought advisable to use a very simple measure.

Test Equipment

STANDARD SIGNAL GENERATOR (S.S.G.)

The procedure described in this report necessitates the availability of two signal generators each having the following performance features.

Frequency Coverage

This shall consist of at least the frequency band or bands which may be allocated to the broadcasting of frequency modulation and also the intermediate frequencies which may be chosen by designers as well as the image frequencies which would result. A signal generator coverage of 7Mc/s to 133Mc/s is tentatively suggested. This range of frequency will not permit tests at oscillator second harmonic ± intermediate frequency.

Frequency Stability (Short Term)

This must be of sufficiently high order to reduce frequency drift during a measurement to within ±1kc/s.

Accuracy of Frequency Setting

The frequency calibration must enable the frequency to be adjusted in not more than 30kc/s steps. A crystal check method should be used to "spot align" the interpolating variable frequency oscillator to an accuracy of not worse than ±0·030 per cent.

Freedom from Hum and Noise Modulation

The unwanted R.M.S. amplitude modulation of the carrier measured after passage through a C.C.I.F. aural sensitivity network (Fig. 1) should be less than 0·1 per cent of that due to 100 per cent sinusoidal amplitude modulation at 2kc/s.

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The frequency modulation caused by hum or noise measured after passage through a C.C.I.F. network should produce an R.M.S. output not exceeding that due to sinusoidal deviation of ±5c/s at 2kc/s modulation frequency.

Frequency Modulation

This must be calibrated in steps of deviation, by a sinusoidal modulation, of at most 5kc/s up to a deviation of ±100kc/s and at most 20kc/s steps up to ±300kc/s. The change of mean frequency due to the application of sinusoidal modulation shall not exceed 1kc/s. The unwanted amplitude modulation caused by a sinusoidal deviation of ±75kc/s shall not exceed 1 per cent, for deviations up to ±300kc/s it shall not exceed 5 per cent.

Sinusoidal Amplitude Modulation

This must be calibrated in steps of at most 10 per cent modulation to a depth of 50 per cent and this depth of amplitude modulation must not cause a peak frequency deviation in excess of ±100c/s.

Modulation Frequency

If internal modulation is to be available, then a 2kc/s frequency must be provided and it would be desirable to have 400c/s and 10kc/s as well. Provision for modulation by an external source should exist and be uniform to within ±1db from 30c/s to 15kc/s.

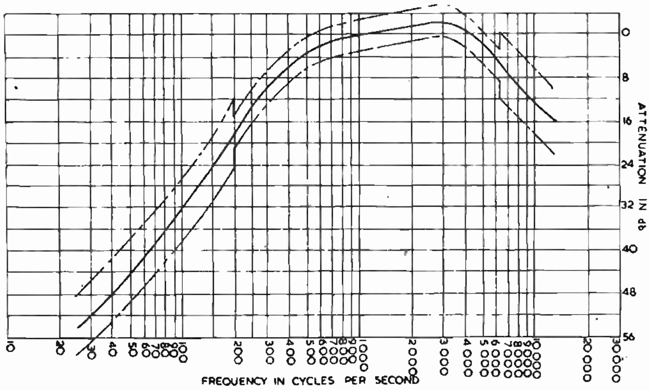


Fig. 1. C.C.I.F. aural weighting curve

Modulation Distortion (Harmonic)

The total R.M.S. harmonic content of the response due to sinusoidal frequency modulation having any maximum deviation up to ±75kc/s and any frequency between 30c/s and 15kc/s should not exceed 1 per cent of the R.M.S. modulation. The R.F. bandwidth of the receiver for measuring this must exceed 180kc/s (±90kc/s).

Spurious Outputs

Any carrier output other than that indicated by the frequency calibration must be at least 60db below the level of the required carrier.

Output Voltage

The open circuit output voltage shall be variable in steps not greater than 2db from 100mV to 1μV. The internal output impedance shall be not greater than 75Ω substantially resistive. The accuracy of voltage calibration shall be not worse than ±1db ±1μV.

OUTPUT POWER NOISE METER

This meter must be capable of measuring the power in waveforms of at least 30db crest factor, and must indicate either the R.M.S. or mean square value of the waveform. The meter should be capable of having a frequency response restricted to that of the C.C.I.F. aural network (see Fig. 1). The meter must be capable of giving a full-scale reading for an input power of 5 microwatts. The indicating instrument, which must be critically damped, should have a time-constant of about 0·5 second.

IMPULSE GENERATOR

In order to investigate the performance of a receiver when receiving impulsive interference it is essential to have a generator of such interference with definite control of the waveform.

The Output Waveform

This shall consist of discrete pulses of short duration and variable pulse repetition rate covering at least the range from 10c/s to 500c/s. If the P.R.F. (pulse repetition frequency) is adjustable by switching to fixed repetition rates one rate shall be 500c/s.

The pulse shape is relatively unimportant provided the pulses are unidirectional and the pulse duration sufficiently short to produce a frequency spectrum consisting of uniformly spaced spectral lines having amplitudes uniform to within ±1db over the frequency range from 100kc/s to 133Mc/s.

Output Voltage

With a P.R.F. of 50c/s this shall be not less than 17·5 R.M.S. μV per square root "integral bandwidth" measured in kc/s and chosen anywhere within the range of 100kc/s to 133Mc/s.

The value of 17·5μV R.M.S. corresponds approximately to 100 peak μV per kc/s of "integral bandwidth" for a pair of bandpass coupled circuits having a coupling parameter $KQ = \sqrt{2}$.

The frequency limits defining "integral bandwidth" shall be those frequencies at which the steady state response has fallen by 20db from the nominal mid-frequency steady state response. In a numerical example, if the "integral bandwith" of a receiver R.F. circuit is Bkc/s the impulses will produce 17·5 $\sqrt{B}$ R.M.S. μV or approximately 100B peak μV.

The Output Attenuation

This shall be in steps of not greater than 2db to 60db below maximum output with a further 20db obtainable by a switch controlling the waveform amplitude before the variable attenuator.

The Output Impedance

This shall be not greater than 75 ohms and shall be substantially resistive.

Test Standards

STANDARD INPUT IMPEDANCE

The tests should all be carried out with the S.S.G. matched to the nominal input impedance of the receiver. This should be taken as 75 ohms unless otherwise stated.

STANDARD LOAD RESISTANCE

The output test load should be a resistance of value equal to the D.C. resistance of the loudspeaker speech coil. While it is admitted that this definition does not accord with actual conditions at all audio frequencies, it is none the less a convenient means of comparison between receivers and is very easily determinable.

STANDARD OUTPUT POWER

This shall be measured in the standard output resistance and shall be 50mW for all types of receivers unless otherwise stated.

STANDARD MODULATION FREQUENCY

This shall be 2kc/s. The reason for this choice is that the C.C.I.F. aural weighting curve (see Fig. 1) presents a maximum at this frequency. In addition, the shape of this curve is such that errors in frequency around 2kc/s give rise to smaller errors in response than at any other convenient frequency.

STANDARD MODULATION DEPTH

This shall be 40 per cent of the maximum nominal depth permitted by the system of modulation in use. In the case of F.M. with pre- and de-emphasis it may be desirable to increase the modulation depth by an amount which will account for the necessary pre-emphasis at 2kc/s. For example, a 50μsec pre-emphasis requires that the modulation depth be increased from 40 per cent to 47·5 per cent at 2kc/s modulation frequency.

STANDARD RATIO OF SIGNAL TO UNWANTED RESPONSE

This shall be taken as a C.C.I.F. weighted 40db ratio between A.F. signal and unwanted response, both being measured with the standard output noise power meter. For this test, standard modulation frequency and depth shall be used, and the A.F. gain control adjusted to obtain standard output.

Test Procedures

Many of the following tests may require to be repeated near the edges of the radio frequency coverage as well as in the centre.

SENSITIVITY

The sensitivity of an F.M. receiver can be expressed as the smallest input signal required to satisfy all the following three conditions:—

(a) a satisfactory listening level [standard output]

(b) satisfactory programme quality [10 per cent distortion for 100 per cent modulation]

(c) a satisfactorily low hum and background noise level [– 40db].

Absolute Sensitivity

This is the S.S.G. "open circuit voltage" required to produce standard output power. Standard modulation frequency should be used, and at standard modulation depth. The receiver gain controls should be at maximum gain for this test.

Maximum Deviation Sensitivity for 10 *per cent Harmonic Distortion*

This is the S.S.G. "open circuit voltage" which, modulated to a depth of 100 per cent at a frequency of 400c/s, unless otherwise specified, gives rise to an audio output distortion of 10 per cent. The bandwidth of the measuring device shall not restrict that of the receiver. This percentage distortion shall be the product of 100 and the ratio: R.M.S. distortion/R.M.S. (fundamental + distortion). The receiver A.F. gain control should be so adjusted that the total output is equal to the standard output. If the distortion is less than 10 per cent at the absolute sensitivity input, then the percentage distortion at this input should be measured.

Sensitivity for Standard Ratio of Signal-to-Noise

This is the S.S.G. "open circuit voltage" required to produce the standard ratio of signal-to-noise.

Signal-to-Hum Ratio

This is the deviation as a percentage of the system's maximum, necessary to produce the standard ratio of signal-to-hum. The carrier input should be 10 millivolts and the standard modulation frequency should be used.

FIDELITY

These tests are intended to measure the performance of the receiver in reproducing the received intelligence or modulation without distortion.

Harmonic Distortion, Variation with Modulation Depth

By suitable adjustment of the receiver A.F. gain control standard output power shall be obtained with standard modulation depth and at a frequency of 400c/s. The R.F. input carrier shall be 10mV. A graph of percentage R.M.S. harmonic distortion against percentage modulation shall be drawn for modulation percentages varying from 0 to 100. The bandwidth of the harmonic measuring device shall not restrict that of the receiver. It may be desirable to repeat this test with a 1mV input.

Maximum Output Power for 10 *per cent Harmonic Distortion*

With an R.F. input carrier of 10mV modulated to a depth of 100 per cent at 400c/s, adjust the A.F. gain control to obtain the maximum output power giving rise to 10 per cent distortion.

Modulation Frequency Characteristic

This is a curve of audio amplitude plotted against modulation frequency at constant modulation depth when the former is varied from 30c/s to 12kc/s. The carrier input shall be 10mV and the audio gain adjusted to produce standard output power with standard modulation depth and frequency. It should be remembered that a uniform curve will not be obtained if the receiver employs de-emphasis.

Audio Frequency Input-Output Characteristic

This test is applicable when the receiver is provided with gramophone pick-up terminals.

With A.F. gain control at maximum plot the curve showing output voltage across the standard load resistance against A.F. input voltage at a frequency of 2kc/s.

SELECTIVITY

The purpose of these tests is to ascertain the capability of the receiver to reject all transmitted signals other than the one to which it is tuned.

Adjacent Channel Suppression Ratio

For this test the receiver shall be adjusted to produce standard output power when tuned to a carrier of 1mV with standard modulation frequency and depth. This modulation shall then be switched off and a second carrier (with standard modulation frequency and depth) tuned to one of the adjacent channel frequencies (±200kc/s from required channel unless otherwise stated). The amplitude of the adjacent channel carrier shall be adjusted until the audio output of the receiver is 40db below standard output power, that is until standard ratio of signal to unwanted response is obtained. The ratio of the adjacent carrier amplitude to required carrier amplitude (1mV) is noted. This test is repeated for both adjacent channels.

Second and Third Channel Suppression Ratios

These are measured as above, but with the frequency separations of ±400kc/s for second channel and ±600kc/s for third channel.

Image Channel Ratio

This is measured as described above with the exception that the second carrier (interfering carrier) is separated from the required carrier by twice the intermediate frequency.

Intermediate Frequency Suppression Ratio

The procedure described above is repeated with the frequency of the interfering carrier adjusted to the intermediate frequency of the receiver.

Spurious Frequencies Suppression Ratios

The procedure described above is repeated with the frequency of the interfering carrier adjusted to any frequency liable to give rise to spurious response. Such frequencies include integral multiples of the intermediate frequency, and various combinations of receiver superheterodyne local oscillator harmonics and the intermediate frequency and multiples of it.

FREQUENCY STABILITY

These measurements are required as a guide to the manual tuning necessary to keep the receiver tuned to a wanted carrier. They are based on the assumption that circuits operating at intermediate frequency will not materially affect the issue.

Oscillator Drift

This test is to ascertain how much the local oscillator frequency changes with temperature increase from first switching on the receiver. The receiver should be switched on and tuned to a stable frequency carrier of 1mV strength. The local oscillator frequency should be measured and changes of this frequency plotted against time until the rate of frequency change with time becomes negligible. Steps should be taken to maintain stable mains voltage.

Dependence of Oscillator Frequency upon Mains Voltage

This test is to ascertain within what limits of mains voltage variation the receiver may conveniently be used. The receiver should be switched on and a sufficient lapse of time allowed for the frequency drift with temperature rise to have become negligible. Tune receiver to a stable frequency carrier of 1mV strength. The mains supply voltage is then varied in 5 or 10 volt steps over such a voltage range as will cause the receiver local oscillator to change appreciably.

From a graph of frequency against mains voltage it is then possible to state within what limits of voltage variation the receiver must be operated.

Co-channel Suppression Ratio

This is to test the receiver performance when receiving a wanted carrier and an unwanted (distant station) carrier on the same frequency.

The receiver should be tuned to a carrier of 1mV with standard modulation frequency and depth. The audio gain control shall be adjusted to produce the standard output

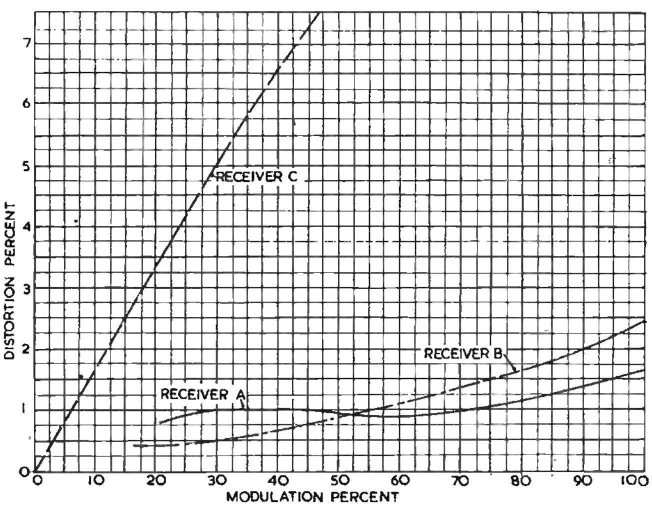


Fig. 2. Variation of harmonic distortion with modulation depth

power as measured with the standard output power noise meter. The modulation shall then be switched off.

A second carrier having standard modulation frequency and depth shall then be connected to the receiver input in parallel with the first (unmodulated carrier) and tuned to within 1kc/s of the same frequency. The amplitude of this modulated carrier shall be adjusted until the standard ratio of signal to unwanted response is obtained. The ratio of this carrier amplitude to 1mV is the required suppression ratio. It may be necessary to re-adjust the receiver tuning for minimum interference in the presence of both carriers.

Amplitude Modulation Suppression

The purpose of this test is to measure the efficiency of the amplitude limiting circuits of the receiver.

The receiver should be tuned to a carrier of 1mV frequency modulated to the standard depth and at standard frequency. The audio gain should be adjusted to produce standard output power. A band-pass filter attenuating frequencies outside the band 250c/s to 8kc/s should be interposed between the receiver audio output and the standard output power noise meter with the c.c.i.f. network in circuit. The frequency of the modulation should then be changed to 10kc/s so that the audio output at this frequency will not be read on the standard output power noise meter. The carrier should then be simultaneously amplitude modulated to standard depth and at standard frequency. The meter will then read the unwanted output due to amplitude modulation while not reading the output due to frequency modulation. The ratio of the standard output power due to frequency

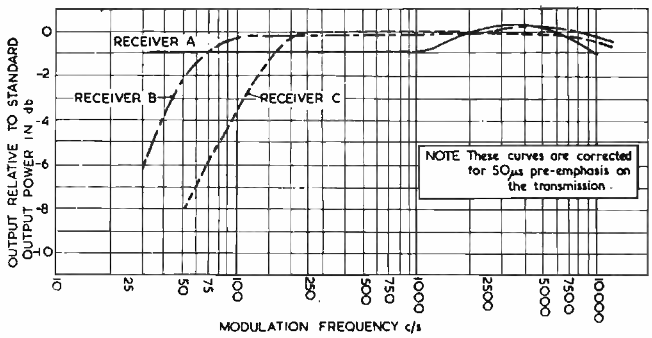


Fig. 3. Modulation frequency characteristic

modulation to the output power due to amplitude modulation should be recorded.

This measurement may be repeated with the wanted carrier increased to 10mV.

Impulsive Interference Performance

This test is intended to show the performance of the receiver when receiving a carrier and impulsive interference. The resulting curve should show this performance for conditions including the improvement threshold of the frequency modulation receiver for impulsive interference.

The receiver should be tuned to a carrier of 0·5mV having standard modulation depth and frequency and adjusted to produce the standard output power. A band-pass filter attenuating frequencies outside the band 250c/s to 8 kc/s shall be interposed between the receiver audio output and the standard output power noise meter. The modulation frequency shall be changed to 10kc/s.

A source of impulsive interference shall then be connected to the receiver input in parallel with the source of frequency modulated carrier.

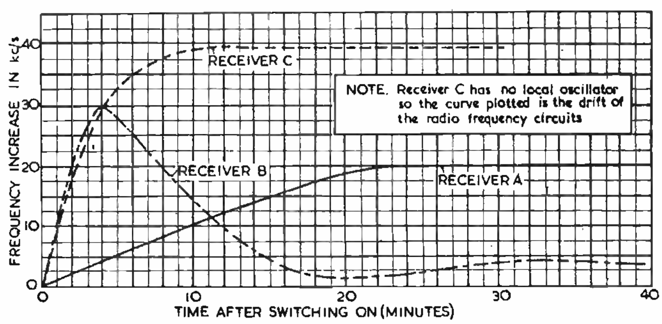


Fig. 4. Oscillator drift

The impulsive interference repetition frequency shall be adjusted to 500c/s unless otherwise stated. A curve is then plotted of c.c.i.f. weighted output power (in the pass band obtained with the band-pass filter) against impulse amplitude in peak μV/kc/s. The impulse amplitude shall be varied from the maximum obtainable down to such a value that further reduction does not affect the receiver output noise level. This test should be repeated with the frequency modulation of the signal generator switched off.

Performance Tests on Three Receivers

Three different types of frequency modulation receiver were tested at a frequency of 90Mc/s according to the procedure described above and the results are reproduced here as typical examples:—

Receiver A. This is a high grade frequency modulation receiver using thirteen valves plus a rectifier.

Receiver B. This is a receiver designed for simplicity compatible with a reasonable performance and uses six valves plus a rectifier.

Receiver C. This is a super-regenerative two valve adaptor intended to supply an audio output to the pick-up terminals of a normal broadcast receiver.

SENSITIVITY

Absolute Sensitivity

Receiver A	52μV
Receiver B	60μV
Receiver C	Not applicable.

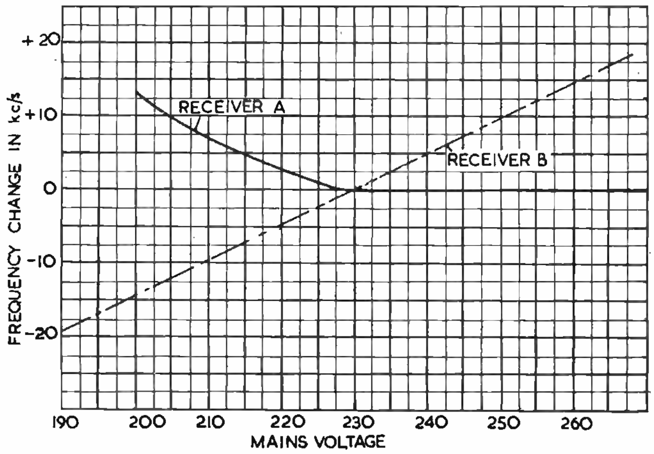


Fig. 5. Dependence of oscillator frequency on mains voltage

Maximum Deviation Sensitivity for 10 per cent Harmonic Distortion

Receiver A	less than 52μV
Receiver B	60μV
Receiver C	With an input of 10mV the distortion is 14 per cent and is greater for all other inputs.

Sensitivity for Standard Ratio of Signal-to-Noise

Receiver A	28μV
Receiver B	25μV
Receiver C	1·0mV

Signal-to-Hum Ratio

Receiver A	2·0 per cent
Receiver B	2·0 per cent
Receiver C	41·0 per cent

FIDELITY

Harmonic Distortion, Variation with Modulation Depth

See Fig. 2.

Maximum Output for 10 per cent Harmonic Distortion

Receiver A	Maximum output power was 3 watts at which the distortion was 3·0 per cent.
Receiver B	2·1 watts
Receiver C	Not applicable but distortion was greater than 10 per cent at all output levels.

Modulation Frequency Characteristic

See Fig. 3.

SELECTIVITY

Adjacent Channel Suppression Ratio

	−200kc/s.	+200 kc/s.
Receiver A	9.0db	− 6.0db
Receiver B	11.0db	− 1.0db
Receiver C	—35.0db	−24.0db

Second and Third Channel Suppression Ratios

	−600 kc/s.	−400 kc/s.	+400 kc/s.	+600 kc/s.
Receiver A	>34 db	>34 db	30 db	>34 db
Receiver B	>34 db	31 db	29 db	>34 db
Receiver C	− 1.8db	− 4.1db	− 9.1db	− 6.0db

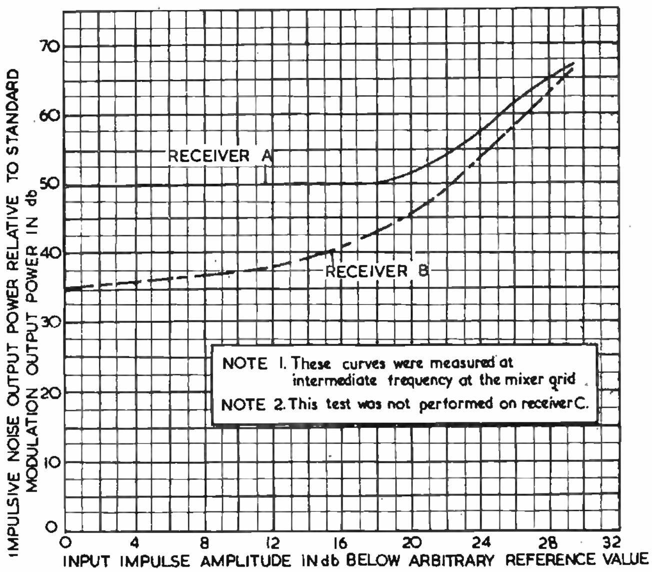


Fig. 6. Impulsive interference performance

Image Channel Ratio

Receiver A	21·8db
Receiver B	12·7db
Receiver C	Not applicable.

Intermediate Frequency Suppression Ratio

Receiver A	32db
Receiver B	>34db
Receiver C	Not applicable

Spurious Frequencies Suppression Ratios

Receiver A	31·6Mc/s	21db
Receiver B	100Mc/s	14db
Receiver C	None	

FREQUENCY STABILITY

Oscillator Drift

See Fig. 4

Dependence of Oscillator on Mains Voltage

See Fig. 5.

CO-CHANNEL SUPPRESSION RATIO

Receiver A	−6db

Receiver B −12·5db
Receiver C −35db

Amplitude Modulation Suppression Ratio
Receiver A 38db
Receiver B 27db
Receiver C 11db

Impulsive Interference Performance
See Fig. 6

Conclusions

From the tests on the three example receivers one may say that as regards sensitivity Receiver A is suitable for the reception of signals greater than 52μV while B requires 60μV or more. Receiver C is inferior to the other two for all values of signal strength. As far as fidelity and selectivity are concerned it can be seen that Receivers A and B are comparable, whereas Receiver C is much inferior. As regards susceptibility to impulsive interference, Receiver A is definitely superior to B, but it was not possible to test Receiver C because of the lack of a suitable impulse generator.

Acknowledgment

The authors are grateful to the Chief Engineer of the British Broadcasting Corporation for his kind permission to publish this work.

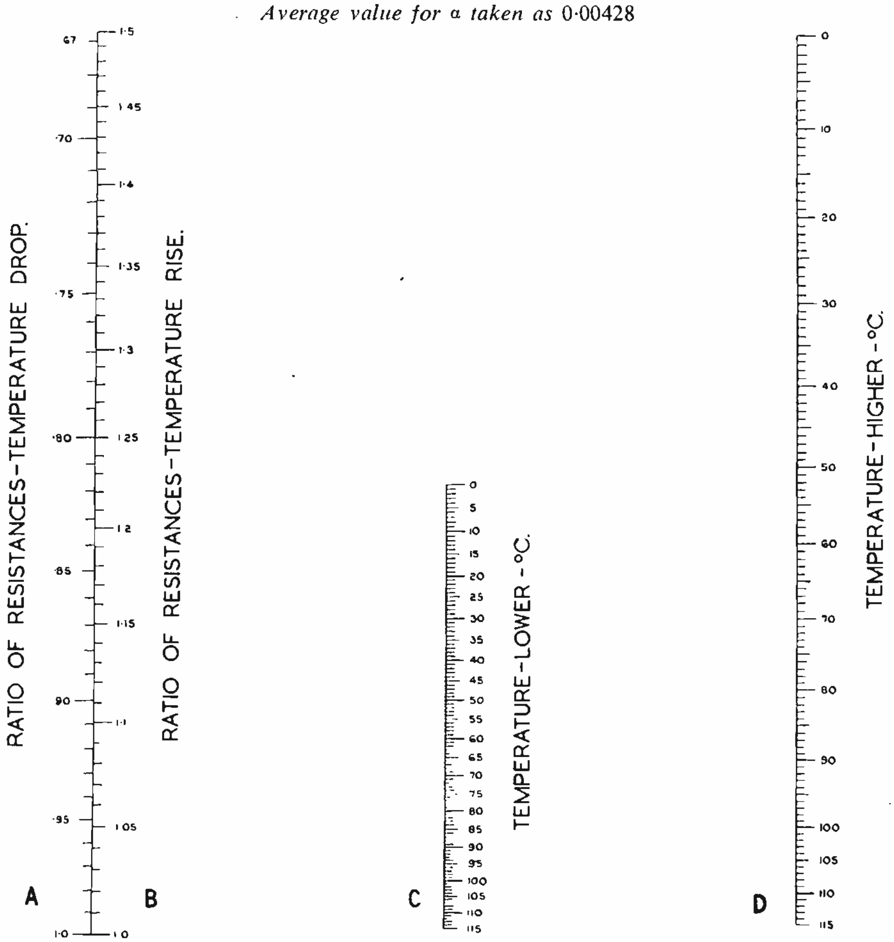
REFERENCE

Maurice, Newell & Spencer: Electrical Noise. *Wireless Eng.*, Jan, 1950.

Temperature/Resistance Chart for Electrical Copper

By A. E. Maine

Average value for α taken as 0·00428



The chart is constructed for determining rapidly the change of resistance with temperature of a unit wound with copper wire alternatively, the new temperature may be found from knowledge of the original temperature and the ratio of resistance change.

To use the chart a straight-edge is laid across the chart, cutting the temperature and resistance ratio scales at the required points. If a fall of temperature is involved, the scale "A" must be used, whereas scale "B" is employed for a temperature rise. The higher and lower temperature points must be located on the appropriate scales, otherwise the straight edge will not align with scales A and B.

Example

A coil whose resistance is 35Ω at 22°C is heated to 85°C, what is its new value of resistance?

Lay a rule between 22°C on scale "C" and 85°C on scale "D". Read the resistance ratio where the rule cuts scale "B", viz.: 1·248. The new resistance is therefore 1·248 × 35 = 43·68Ω.

A Recording and Integrating Flowmeter

By D. C. Pressey * B.Sc.

An instrument is described whereby rapidly varying flow-rates may be measured or recorded together with the volume which has passed. It comprises a simple flow resistance transforming flow rates to pressures, an electrical capacitance manometer of variable sensitivity, and an electrical integrator to give volume readings.

The ranges of flow-rates, pressures, and volumes, for which full output is obtained are:—

1. *Flow-rates.* 0·05-3 *litre/sec.* *Accuracy* ± 3·5 *per cent*
2. *Pressures.* 1-50*mm of water.* „ ± 2·5 *per cent*
3. *Volumes.* 0·1-75 *litres.* „ *normally better than* ± 6·5 *per cent.*

These accuracies are obtained if the internal calibration is used. The instrument has been designed primarily for respiration studies.

IN order to investigate the effect of anæsthetics on human respiration, an instrument for instantaneous recording of respiratory flow-rate and inspired volume was required. It was essential that it be safe for use in the presence of explosive anæsthetic mixtures. Further desiderata were stability, mobility, simplicity of operation, and ruggedness.

For the present application, it was thought that measurement of flow-rates up to 2 litres/sec would be adequate, and that a resistance of 40mm of water—at this peak flow-rate—could be tolerated by the patient for short periods.

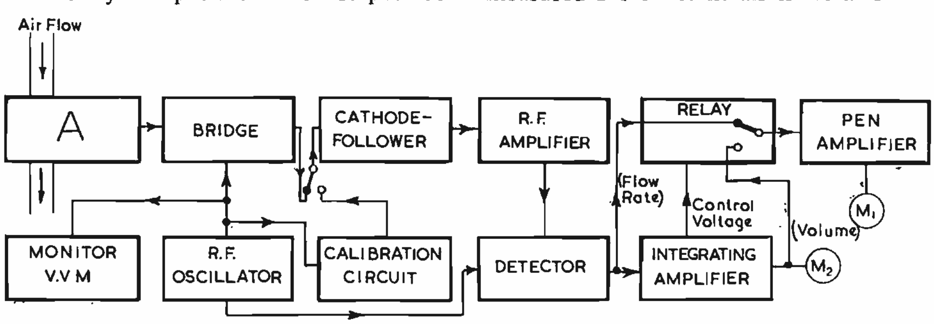


Fig. 1. The complete system

The unit A consists of a flowrate/pressure transducer and a capacitance pressure gauge

Method

An instantaneous recording in the frequency range 0-100c/s is given only by an electrically driven pen-writer, so an electrical method is used. As all anemometers using hot wires are unsatisfactory because of the explosion risk, it was decided to convert variations in flow into variations in pressure, and to measure these with a capacitance manometer. A block diagram of the system is given in Fig. 1. Flow-rates are indicated on meter M_1; volumes on meter M_2. Both may be recorded.

In normal use inspirations only are recorded and integrated. A non-return valve ensures that the patient only inspires through the resistance, hence all pressure signals are one way.

The components of the system will now be considered in order.

Flow-rate Transducer

Previous experience with an optical flow-rate recorder (1940 unpublished) would have favoured a flow-rate pressure difference transducer based on the Venturi tube. However, for reasons discussed in the next section an electrical circuit was chosen for the capacitance manometer which is best suited for a linear relation between pressure signal and final voltage output. No discussion of suitable transducers causing a pressure loss approximately proportional to the flow-rate is intended at present (e.g., Fleisch[1]).

One of the transducers used in preliminary experiments with the flow-rate recorder consists of a closely packed layer of fibrous material, ½in. thick and with a cross section of 12sq.in. The pressure loss of this unit was measured for constant air flows at room conditions up to 2·5lit./sec (see Fig. 2). The pressure loss p rises more steeply than linear with the flow-rate F and the characteristics can be approximated by a parabolic expression: $p = 17{\cdot}1\ F + 1{\cdot}16\ F^2$; the unit for the pressure loss is millimetres of water, for the flow-rate lit./sec. For quiet breathing during anæsthesia the peak flow-rate is of the order ½lit./sec and the pressure loss in this transducer 8·8mm of water, a value which deviates by only 3 per cent from a strictly linear relation. The corresponding values for F = 1lit./sec are p = 18·3mm of water and a deviation of less than 7 per cent from a linear relation between F and p.

Capacitance Manometer

Historical Review

Many capacitance manometer circuits have been described and have been considered. Only those which could be used for the present application will be mentioned.

The early resonance-curve circuits[2,3] being direct-coupled throughout, are unlikely to be very stable.

Various systems incorporating variable frequency oscillators have been described,[4,5,6,7] but the attainment of long-term stability with two or more tuned circuits is difficult.[5,8,9] However, the stability inherent with fixed frequency

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oscillators has been utilized, and several recent circuits[10,11,12,13,14] have the further advantage that lead capacitance changes can be overcome. From the literature it would appear that Walker's[12] modification of Frommer's[11] circuit is the most stable and satisfactory. The earlier circuit of Békésy[10] overcomes lead capacitance changes by the same principle, and may be better for some applications. In the circuits of references[11-14] the signal is the out-of-balance voltage from a bridge.

The advantages of a system comprising a fixed-frequency (crystal) oscillator, bridge-modulator, and carrier frequency amplifier, are:

(1) High-stability.
(2) Low-level D.C. amplifiers are eliminated.
(3) Lead capacitance changes can be overcome by the choice of a suitable bridge.
(4) Calibration simple.
(5) Wide frequency response—from zero to c. 1/5 of the carrier frequency.
(6) Linear output versus pressure relationship obtainable.
(7) High sensitivity obtainable.

THE METHOD USED

The circuit used,* Fig. 3, like that of Goodall and Smith,[15] is a 4-arm capacitance bridge, and advantage (3) is not realized. Capacitances only are used in the bridge network, as they are cheaply obtainable, of small size, and of low temperature coefficient. Wire wound resistances, though of low temperature coefficient, produce "current noise".

The Oscillator

A frequency and amplitude stable oscillator is essential, and frequency stability is achieved by the use of a Miller crystal oscillator.[16] Amplitude stability is obtained by using a constant voltage transformer T_5, stabilized H.T., and high-stability carbon, or wire-wound, resistors. The alternative would be automatic amplitude control.[9,17] A small "noise" amplitude modulation (A.M.) is detectable,

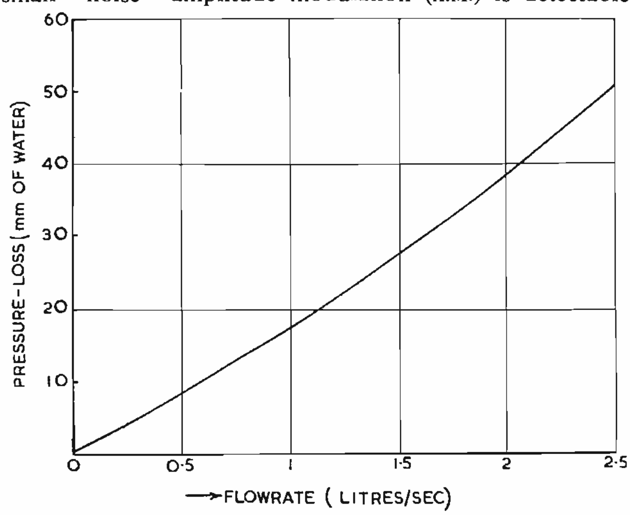
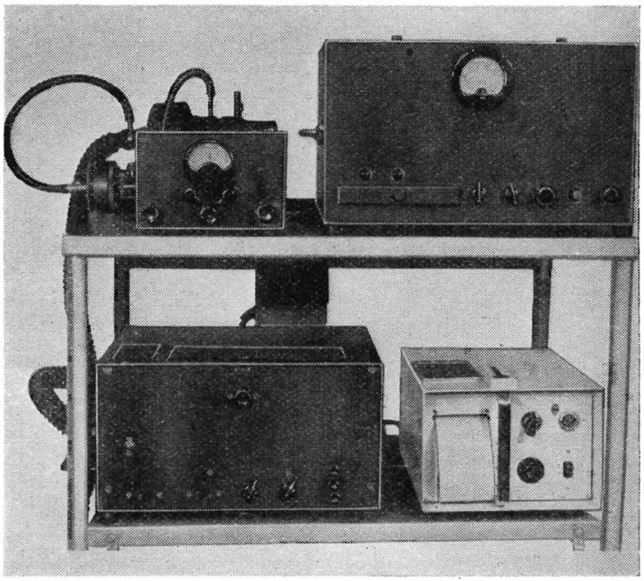


Fig. 2. Calibration of flowrate/pressure transducer

this is minimized by valve selection and by the use of "noise-free" resistors in the voltage supplies. The valve is anti-microphonically mounted to reduce A.M. by microphony.

The choice of frequency is a compromise, the relevant factors are that: (a) R.F. is preferable to an A.F. because compact high gain R.F. amplifiers can be made, and because bandwidth increases with frequency. (b) Because of physical limitations, the capacitance of the gauge is most likely to be 10-100pF. An upper limit is thus set on the frequency, which determines the bridge impedances, by the requirement that the unbalance voltage produced by the bridge is large enough to give a good signal-to-noise ratio. An oscillator supplying 4V R.M.S. at 164kc/s has been found satisfactory—though a greater voltage would be preferable.

A monitor valve-voltmeter is provided for convenience (V_8 and M_3, etc).



The complete instrument.

The Bridge

In this, the components are all of high stability.

Capacitance balancing is done with C_4, and phase balancing with the smallest possible wire-wound potentiometer, P_1, (20 ohms).

The bridge arms are each of 100pF. This value of capacitance is large compared with the "strays", yet it permits the gauge to be of reasonably small dimensions.

A fully screened toroidal dust-cored transformer is used for T_3, otherwise the stray coupling between the windings produces a phase-unbalance, and the larger phase balance potentiometer needed causes temperature drift.

The ratio of output (i.e., unbalance) voltage, to input voltage, is given by

$$V_0/V = 1/2 \frac{\Delta C}{2C + 2C_D + \Delta C\,(1 + 3C_D/C)}$$

where $C_1 = C_2 = C_3 = C_4 = C$, ΔC is any change in C_1 due to pressure, and C_D is the input capacitance of the first stage. (V_1).

An experimental voltage/incremental capacitance ΔC curve for the bridge is given in Fig. 4, together with the ΔC versus pressure curve for the gauge. The former relationship is such that the overall pressure *v* output characteristic for both $\pm\Delta C$ becomes less non-linear.

The Carrier Amplifier

This is conventional, and linear. Sensitivity control is provided by VR_1 and switch SW_2. The maximum gain is c.5000.

Diode Detector

Diode detectors are inherently non-linear for small signals. Non-linearity can be overcome by operating the bridge in an unbalanced condition, but this has the disadvantage that the balance has to be altered when the sensitivity is changed. Since, in this application, the capa-

* *The circuits given in references (10, 11, 12) seem eminently satisfactory, but were not known to the author when this instrument was built. Freedom from zero drift is not claimed for the circuits of references (13, 14).*

citance changes ΔC are of one sign, the voltage signals are of one phase. The origin distortion can thus be overcome by applying to the suppressor grid of the final R.F. amplifier V_3 a fraction of the oscillator voltage to produce about 3V R.M.S. at the diode anode. The phase is selected by switch SW_4. Linear detection of signals is thus achieved. Output from the detector, for the integrator or an oscilloscope, is taken from socket S_1. The signal required to drive the pen amplifier is 11·9 volts; the noise is c.10mV peak-to-peak—mainly hum from the diode.

The Pen Driver Amplifier

This is economical in H.T. consumption, and gives an output of 120V (across 5kΩ anode-to-anode) from an input of 11·9V. This gives a deflexion of 11mm. The output would be 125V (and deflexion 11·4mm) if it were perfectly linear. The accuracy of reading, expressed as a percentage of the maximum, is c. ± 5 per cent from the records, and better than ± 1 per cent from the meter M_1.

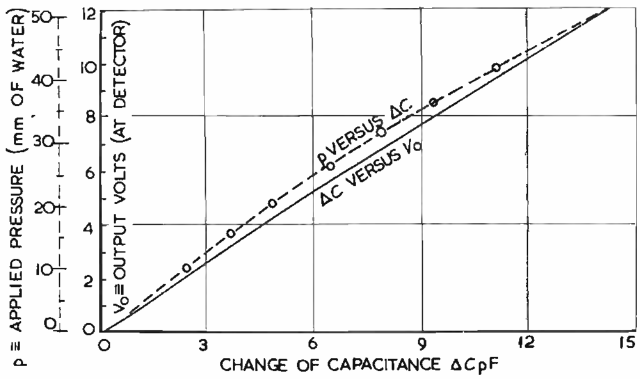


Fig. 4. Pressure versus ΔC for the gauge and ΔC versus detector voltage for the bridge

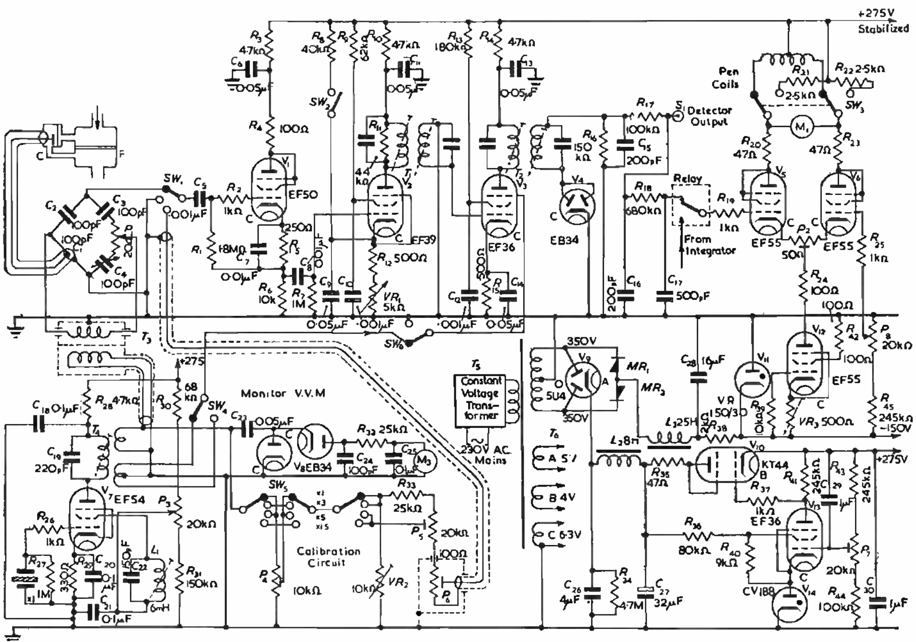


Fig. 3. The capacitance manometer

All potentiometers and variable resistors are wire-wound

OPERATION AS MANOMETER OR FLOWMETER

For pressure measurement greater sensitivity is obtained if the gauge is connected so that ΔC is positive. (Fig. 5). Greater linearity could be obtained by feedback over the R.F. amplifier.* For flow measurement the gauge is connected so that ΔC is negative. The manometer non-linearity then opposes that of the flow transducer. (See Figs. 2, 5, and 6). In operation the bridge is normally balanced (with C_4 and P_1) but for alternating pressures or flows the pen (or meter M_1), set to one side with the shift control P_8, is centred by adjusting C_4.

The resistive load R_{21}, R_{22}, enables the instrument to be used without the pen writer.

Once the instrument has been calibrated, it may be reset to any desired sensitivity by means of the internal calibration voltages provided by switch SW_5, etc., and applied to the R.F. amplifier through SW_1. The voltages are adjusted so that the setting accuracy in the range 1-50mm of water is never worse than ± 2·5 per cent.

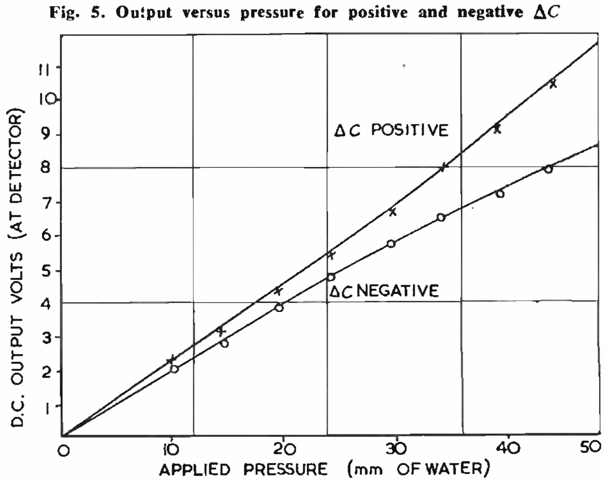
The Integrator and Associated Relays. Fig. 7

Only a brief description of the circuit and its working will be given. The first stage V_1 is a cathode follower. Stage V_2 is a linear amplifier[18] of gain (× 20) such that the output from the detector produces maximum permissible anode swing, c.200V. Stage V_5 is a Miller integrator. Two time-constants, giving two ranges, are provided. The capacitors C_1 and C_2 have leakage resistances of 1,000MΩ and 5,000MΩ respectively. The phenomenon of " soaking " is experienced slightly, and polystyrene dielectric capacitors for C_1, C_2, would be preferable. Switch SW_1, which has three contacts used in the manner of guard rings, and the relay contacts A_1, B_1, are tested for leakage resistances greater than 10,000MΩ. The " Miller jump " is eliminated by returning the grid of V_6 to −3·7V (= zero signal) for resetting. This produces a voltage drop of 3·7V across the anode load. The anode current is 80μA and the meter M_2 (0-5mA) is set to read zero with this current.

The screens V_1 and V_5 are fed from series stabilizers V_3, V_4, as decoupling capacitors are impracticable at respiration frequencies (c.10 respirations per minute).

The signal from V_2 is RC coupled to a limiting amplifier V_6, V_7, V_8, the output of which is differentiated and fed

Fig. 5. Output versus pressure for positive and negative ΔC



* *This is done by Hagendoorn and Reynst[14], but the circuit is not given. The usage is like that of A.V.C. in a radio receiver.*

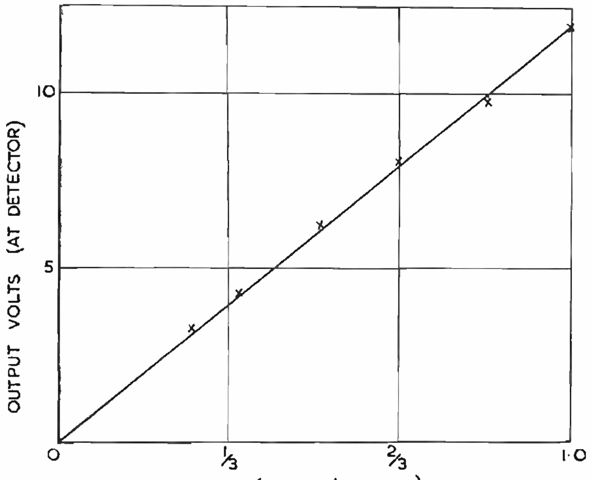


Fig. 6. Output/flowrate relationship at 1 lit/sec sensitivity

to a Schmitt trigger pair[19] V_9, V_{10}. The anode current of V_{10} controls the relay *A*, which controls the relays *B*, and *D*, in turn. The trigger pair operates from a 60mV input, i.e. ½ per cent of maximum signal.

In operation, the inspirations produce negative-going input signals, so that relay *A* becomes energized. After about 20msec the relay cycle is complete and integration commences. The error introduced by this delay is negligible with normal breathing. At the end of the breath the signal amplifier is disconnected from the integrator grid, and the reading of M_2 will remain sensibly constant for five minutes, or until another signal arrives. (With switch SW_3 open.) Due to the finite time-constant of the coupling C_4, R_{37}, (19 seconds), integration ceases before the end of a breath—which lasts 1-3 seconds. The error introduced is normally less than ½ per cent. When switch SW_3 is closed the integrator will reset to zero automatically. The times required for resetting are: Range I 120msec. Range II 1·4sec, but in order to permit good reading or recording of the volume, the onset of the resetting process is delayed by 0·8sec. (Relay contacts B_3, B_4, and C_3 and R_{34}.)

Reading accuracy from meter M_2 is ± 1 per cent. Provision is made to record volumes during the expiration periods. (Relay *D* and contacts.)

For integration of constant flow-rates, and to facilitate zero setting, push-buttons PB_1, PB_2 are incorporated which operate the Schmitt trigger, giving a manual, integrator on/off control.

The relays are constructed from standard P.O. type relays. Stabilized power supplies of 50mA at 300V and 4mA at −150V are required.

Results

The sensitivity of the gauge is 0·23pF/mm of water, and the maximum sensitivity of the manometer circuit is 480 volts/pF. Full output, 120V or 11mm deflexion, can be obtained from pressures in the range 1-50mm of water. The non-linearity at 10mm is 3 per cent, and at 50mm is 15 per cent.

With the present transducer, the corresponding flow-rates and volumes are tabulated below:—

p (mm of water)	*F* (1/sec)	Volume (litres)	
		Range I.	II.
1·43	0·083	0·167	2·5
50·3	2·5	5	75

The non-linearities at 1 lit/sec and 2·5 lit/sec are < 1 per cent and < 4 per cent respectively.

The integrator is linear within the accuracy of the meter M_2 (c. ± 3 per cent) for input signal voltages between 0 to 14V, and for times of, Range (I) 0-8sec, Range (II) 0-120sec, where these times refer to integrating time and not to total duration of the measurements.

For quiet breathing the peak respiratory flow-rate does not exceed 1 lit/sec. At this sensitivity the volume meter M_2 reads, (I) 2 litres, and (II) 30 litres, full scale. These ranges are thus suitable for measuring breaths—from 0·3-1 litre, and minute volumes—6-15 litres.

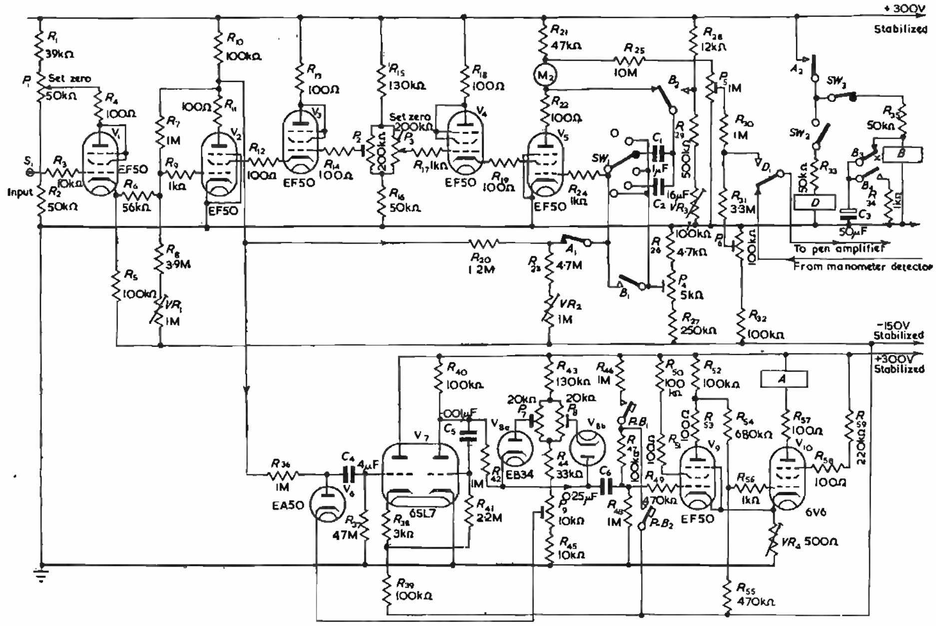
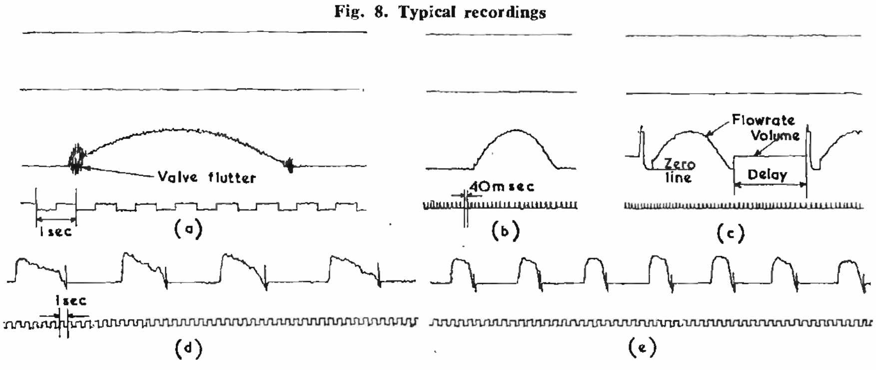


Fig. 7. The integrating amplifier and associated relays shown in "integrate" position

R_{21} High stability carbon
V_6 selected for low grid current

Fig. 8. Typical recordings



External and internal temperature changes affect the bridge components, causing zero drift, and as the chassis is massive a warm-up time of one hour is required, during which time the gain falls by about 10 per cent, also because of temperature changes. Drift at 1 lit/sec sensitivity does not exceed 1V (on M_1) per °C so that in suitable surroundings the controls do not need adjustment from day to day.

Mains fluctuations (± 10 per cent) have negligible effect.

The instrument is believed to be of wide application. In addition to respiration studies, flow (or resistance) characteristics of valves, anæsthesia machines, etc., can be studied. A few typical recordings are shown in Fig. 8.

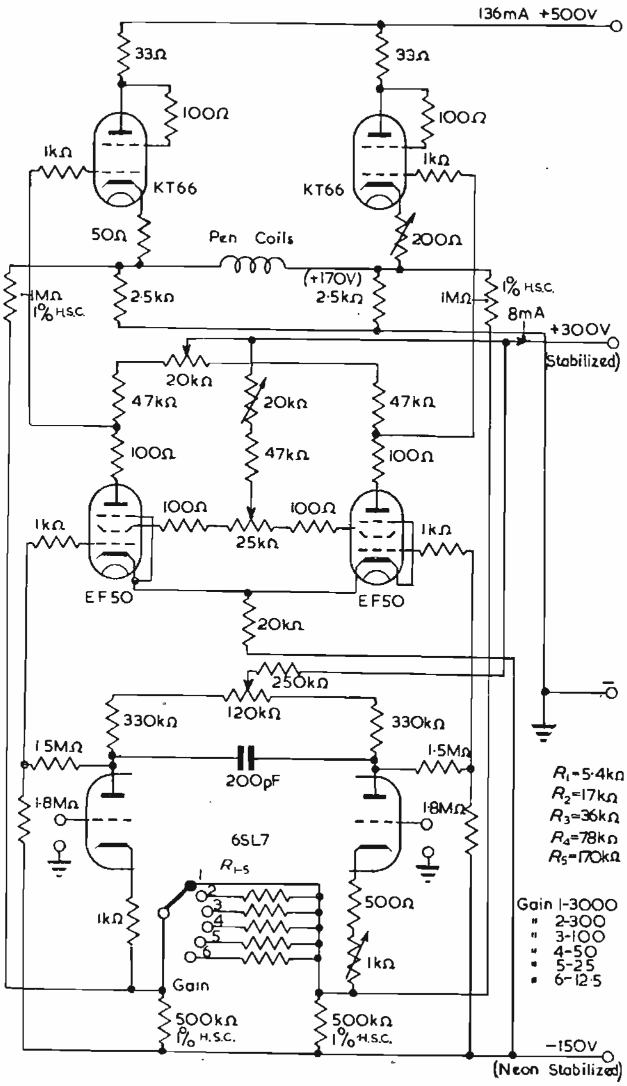


Fig. 9. Pendriver amplifier

As shown this provides ± 150V across the pen coils. Where this voltage is not required the current in the KT66's can be reduced

Records (a), (b), (c) were made with a pump providing a sinusoidally-varying flow, and a non-return valve. The time base runs from left to right. The volume of the stroke is 464cc in all cases. Record (a), Speed is 10.7 respirations per minute, and peak flowrate 15.4 lit/min. (b) Speed 28·8 R.P.M., peak flowrate 40 lit/min. (c) As (b) but with the volume recorded. It is indicated by the height of the horizontal line above the base line during the delay period. At the end of the delay the integrator resets to zero. (d) and (e) Examples of the many breathing patterns. Inspirations only are shown. It can be seen that the non-return valve used was not closing properly. Peak inspiratory flowrate is c.50 lit/min in both cases. Average inspired volume is 1 litre in (d), and 680cc in (e).

Suggested applications include recording of low frequency heart sounds, or barometric fluctuations.

Further Developments

As described, the instrument is properly suited for use only in the laboratory, having a number of disadvantages:

(1) The lead used to connect the gauge into the bridge is sensitive to temperature changes and mechanical displacements. It is also short c.4ft.

(2) Large bulk.

(3) The pen is not heavily damped at its resonant frequency (c.80c/s) nor can it be fully driven.

Since this paper was first accepted a new instrument has been constructed in which these are overcome.

The manometer has been rebuilt as a unit 7in. by 6in. by 5in. The frequency has been changed to 500kc/s so that miniature intermediate frequency transformers could be used. The gauge is attached to the side eliminating the lead troubles.

The pen amplifier (Fig. 9) is linear, of low output impedance, and supplies the 5·5W peak power needed to fully deflect the pen (± 12mm). Conventional power supplies and time markers are built in with it. The amplifier gain is sufficient to permit the differential of the flow-rate to be recorded. The photograph shows the rebuilt instrument.

Acknowledgments

The author wishes to thank Dr. H. G. Epstein, with whom this work has been done, for his considerable assistance both with the work and this paper. He is also indebted to Mr. R. H. Salt for constructional work, and to Miss M. McLarty for preparing the original figures.

REFERENCES

1 FLEISCH, A. : Pflüger's Archiv. *f.d. ges. Physiol.*, *209*, 713, (1925).

2 LILLY, J. C. : An electrical capacitance diaphragm manometer. *Rev. Sci. Inst.*, *13*, 34 (1942).

3 BROOKES-SMITH, C. H. W., COLLS, J. A. : The measurement of pressure, movement, acceleration, and other mechanical quantities by electrostatic systems, *J. Sci. Inst.*, 16, 361 (1939).

4 BRADLEY, W. *Electronics*, *19*, 88 (October, 1946).

5 DYMOND, E. G. : The Kew Radio Sonde. *Proc. Phys. Soc.*, *59*, 645 (1947).

6 HANSEN, A. T. : Pressure measurements in the Human organism. *Acta. Physiol. Scand.*, *19*, Supplementum 68, (1949).

7 SARGROVE, J. A. : The Phasitron. *British Kinematography*, *12*, 90 (1948).

8 LEA, N. : Notes on the electrical stability of oscillators. *J. I. E. E.*, *92*, Pt. IIIA, 261 (1945).

9 GOURIET, C. G. : High-Stability oscillator. *Wireless Engr.*, *27*, 105 (1950).

10 BEKESY, G. von : Uber die Messung der Schwingungsamplitude der Gehörknöchelchen mittels einer kapazitiven Sonde. *Akustische Zeitsch.*, *6*, 1, (1941).

11 FROMMER, J. C. : Detecting small mechanical movements. *Electronics*, *16*, 104 (July, 1943).

12 WALKER, A. H. B. : Improved electronic engine indicator. *Engineering*, *162*, 361, (1943).

13 ROESS, L. C. : A condenser type high-speed engine indicator. *Rev. Sci. Inst.*, *11*, 183 (1940).

14 HAGENDOORN, P. J., REYNST, M. F. : An electrical pressure indicator for internal combustion engines. *Philips Tech. Rev.*, *5*, 348 (1940).

15 GOODALL, S. F., SMITH, R. B. : Instantaneous fluid pressure recording. *Engineering*, *148*, 127 (1939).

16 CREIGHTON, J. L. : Crystal oscillators and their application to radio transmitter control. *J.I.E.E.*, *94*, Part IIIa, 331 (1947).

17 HEAD, J. W. : Thickness gauge for moving sheets. *Electronics*, *21*, 90 (May, 1948).

18 WILLIAMS, F. C. : Circuit techniques for radiolocation. *J.I.E.E.*, *93*, Part IIIa, 303 (1946).

ADDITIONAL REFERENCES

LOVERING, W. F., and WILTSHIRE, L. : A bridge for measurement of the dielectric constants of gases. *Proc. I.E.E.*, *98*, Pt. II, 557 (1951).

PRESSEY, D. C. : Temperature stable, capacitance pressure gauges. *To be published shortly.*

Proportional Temperature Control

By R. Scott, B.Sc., Ph.D.

CONTROL of thermostat heating by a simple on/off method often leads to considerable temperature oscillation.[1] This can be avoided by a proportioning arrangement which, under equilibrium conditions, controls the power dissipation in the heater so that thermal losses are accurately balanced. Saturable inductors have been recommended for proportional control of heating[2,3] but these require a fairly large saturating current with a correspondingly large final valve and power pack. In addition, when the system is far from the equilibrium temperature the final valve may be damaged by excessive current unless protected by a limiting device.[4] Saturable inductors, being somewhat insensitive, require an appreciable potential swing in the grid of the final valve. If,

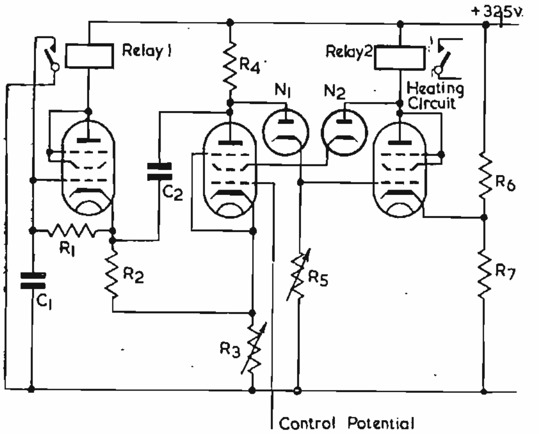


Fig. 1. The control circuit

V_1, V_2, V_3—Mullard EF50
N_1, N_2.—0.5W 230-240V Osglim neon indicator lamps.
R_1 4MΩ
R_2 5,000Ω
R_3 50Ω (preset)
R_4 60,000Ω
R_5 10,000Ω (preset)
R_6 25,000Ω
R_7 500Ω
C_1 value dependent on timing interval (0.1 μF for about 10 secs. in the present circuit).
C_2 0.01 μF.
Relay 1.—1,000Ω, minimum operating current 12.5mA.
Relay 2.—10,000Ω, minimum operating current 3mA, current under operating conditions 10mA.

therefore, thermal losses change in the controlled system, the new equilibrium temperature may differ considerably from that previously set.

As an alternative to the use of saturable inductors, a means of controlling power dissipation can be envisaged employing the switching of the heater for various fractions of a continuously repeated timing interval whose repetition rate is sufficiently rapid for the instantaneous power fluctuations to be absorbed mainly by the thermal capacity of the heater. In the sensitive proportional device to be described, the temperature-dependent control potential can be derived from a temperature-sensitive resistor in a Wheatstone network.[2,3] To suit the following description, this potential is assumed to become less negative with respect to "earth" as the thermostat warms to operating temperature.

With reference to Fig. 1, V_1 and its associated circuit form a slow time-base. The potential drop across R_2 + R_3 charges C_1 through R_1, the anode current and cathode potential of V_1 rising meanwhile.[5] Eventually, when relay 1 operates, C_1 is momentarily short-circuited and the anode current reduced again to a small value. By virtue of R_3, the cathode and anode potentials of V_2 rise during the charging of C_1. At the end of the cycle, during the rapid reduction of current in V_1, C_2 transmits a negative pulse, whose object is to reset the trigger circuit forward by V_2 and V_3.

This trigger circuit has two very stable states. If the anode potential of V_2 is too low to permit N_1 to strike, V_3 is cut off by the potentiometer action of R_6 and R_7. The high anode potential of V_3 allows N_2 to supply screen current to V_2. Under the action of the time-base valve V_1, the anode potential of V_2 normally rises until N_1 strikes. The trigger circuit then attains its other stable state with V_3 taking a large current (adjustable by R_5) and operating the relay in its anode circuit. N_2 being cut off, denies screen current to V_2 which has no further control over V_3. Once in this state, the trigger circuit could not revert to its former condition, were it not for the negative pulse via C_2 which cuts off V_3 on the time-base fly-back and allows V_2 to regain control.

If the control potential is very negative when the thermostat is cold, N_1 remains lit while relay 2 maintains the heater permanently on. As the thermostat warms up, the control potential is so reduced that N_1 does not initially strike. This is accomplished after a portion of the timing cycle has elapsed, i.e., when the anode potential of V_2 has been raised sufficiently by the action of V_1. Relay 2 switches on the heating for this remaining portion only of the total time. Should the thermostat overheat, the con-

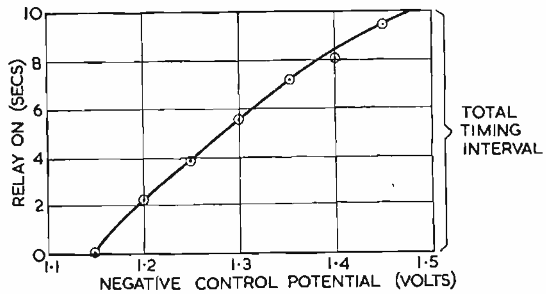


Fig. 2. Operating time/control potential

trol potential becomes so low that, despite the action of the time-base valve, N_1 does not strike. All possible ratios of "on" to "off" time are obtained by a small control potential swing determined by the setting of R_3. For R_3 equal to 20 ohms, a potential swing of about 0.3 volts can give all possible ratios as shown in Fig. 2.

From the practical viewpoint, since correct operation of the circuit can be ascertained from the discharges in N_1 and N_2, these lamps can be mounted in a convenient position on the complete controller. For stable operation, R_5 must be adjusted so that the voltage drop across the coil of relay 2 is large enough with N_1 lit to extinguish N_2. If necessary, a resistor can be added in series with the relay coil to eliminate sustained oscillations from this cause.

Although not so far attempted, temperature variation in a predetermined manner should be possible with this circuit provided the corresponding control potential could be derived. For this application, the high tension supply would require to be stabilized and the input control potential preferably increased by changing the setting of R_3.

REFERENCES

1 HOSELITZ, K., *J. Sci. Inst.*, *22*, 96 (1945)
2 COATES, G. E., *J. Sci. Inst.*, *21*, 86, (1944)
3 ROBERTS, M. H., *Elec. Engg.*, *23*, 51, (1951).
4 YATES, E. L., *J. Sci. Inst.*, *23*, 229, (1946).
5 SOWERBY, J. M., *Wireless World*, *55*, 50, (1949).

The Design of
Series - Parallel Valve Voltage Stabilizers

By F. A. Benson,* M.Eng., A.M.I.E.E., M.I.R.E.

THE simple series-parallel valve voltage stabilizing circuit of Fig. 1 is well known and has recently been described in some detail by the author,[1,2] by Seely[3] and by Elmore and Sands.[4] Scroggie[5] has also published several articles discussing the practical design of this type of stabilizer. It has also been explained, by the author, how additional devices may be included to obtain better stabilization and the improved circuit of Fig. 2 results. It should be remembered that variations in output voltage V_0 are produced chiefly by changes in input voltage and load current. In Fig. 2 these latter changes are used to give additional correction factors. If the input voltage changes a variation is produced in the grid voltage of valve V_1 by way of R_6, the potentiometer chain $R_2R_3R_4R_5$ and the amplifier valve V_2. In this way the voltage drop across V_1 changes to oppose the change in input voltage and a variation of output voltage is prevented. Again, a change in load current produces a change in the voltage drop across R_7 which is applied to the grid of V_1 via the potentiometer and the amplifier valve V_2. The output voltage change can thus be counteracted.

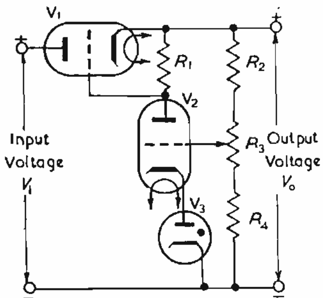


Fig. 1. Simple series-parallel stabilizer

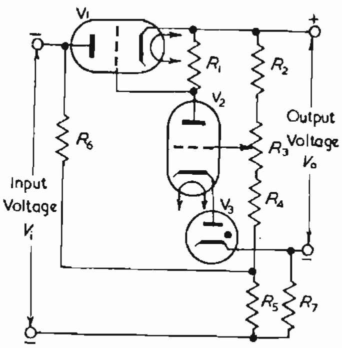


Fig. 2. Series-parallel stabilizer with correcting devices

This type of stabilizer, either with or without the additional correcting devices, is now widely used. There still appear to be many, however, who do not fully understand or appreciate all the problems involved in the design and it is felt that a general discussion of those parts of the subject which are not so well known will be of considerable value.

The Additional Correcting Devices

The correcting device described above in which R_6 is added to provide stabilization against input-voltage variations will be seen to be imperfect because it will vary as the load current changes. This imperfection is usually not very serious and the correction is generally adequate. It might be pointed out, however, that a correction which approaches perfection can be obtained, if so desired, by taking the top end of R_6 (Fig. 2) to a separate rectifier which is not supplying a varying load current but which is fed from the same mains supply.

Both the additional correcting devices depend on the gain of the amplifier valve V_2. The importance of this has been determined by checking the stability of a typical circuit for 12 different amplifier valves of the same type (in this case the EF50). The circuit tested was one providing 300V at 0 to 200mA.

Table 1 gives the figures obtained for the various valves with R_3 set to its optimum position in each case. It will be noticed that there are considerable variations in these figures and hence, for some purposes, it may be found desirable to choose a good valve. On the other hand, even the largest variation recorded will not be serious for most applications. It is probably reasonable to assume that other types of amplifier valve will give similar results.

A pentode is commonly used as the amplifier valve although triodes are shown in Figs. 1 and 2. Some correction for mains input variations may, in this case, be obtained by supplying the screen grid of the pentode from a suitable potentiometer across the unstabilized output voltage from the rectifier. It should be remembered, however, that screen-grid voltage/anode-current characterestics of any particular type of valve may vary considerably from valve to valve or with life.

Valve Sample	Voltage Variations (V)	
	Load Current Varied from 0-200mA. Input Voltage Constant	Load Current Constant. Input Voltage Varied by ±15 per cent*
1	0.8	0.5
2	0.78	0.22
3	1.34	0.32
4	1.72	0.84
5	1.4	0.3
6	0.54	0.98
7	0.9	0.54
8	0.94	0.4
9	0.9	0.5
10	0.82	0.35
11	0.85	0.5
12	1.02	0.46

**Heater voltages of valves kept constant in this test.*

Table 1. Variation of stability of a typical stabilizing circuit with change of amplifier valve

It has been suggested that a capacitor from the positive side of the output voltage to the grid of V_2 might be fitted to reduce hum. This is frequently done and the value of the capacitor is not critical; 0·1 to 0·2μF is generally quite satisfactory. If this capacitor is fitted, however, the correcting circuit involving R_5 must be used with caution as the regulation of the circuit will be better at hum frequencies than at lower ones. In cases where a very low output impedance is required for frequencies below about 30c/s it may be necessary to remove this capacitor at the expense of increased hum.

The Choice of Rectifier Unit and Series Valve

In designing the rectifier unit and choosing the series valve two conditions must be satisfied. First, the rectifier unit must be capable of delivering a voltage equal to the sum of the maximum output voltage and the voltage drop in the series valve, at minimum mains supply voltage and at maximum load current. Secondly, the specified anode power rating of the series valve must not be exceeded.

Consider the equivalent circuit of the stabilizer shown

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in Fig. 3(a). Since V_i and V_o remain constant for all values of I_l, the circuit can be simplified to the one shown in Fig. 3(b) if it is also assumed that I_l is large compared with the current through the controlling element.

The power dissipated in the series valve (W) is thus $= (V_i - V_o)^2 \cdot R_s/(R_s + R_r)^2$.

This is a maximum when $dW/dR_s = 0$, i.e. when $R_s = R_r$. Thus the power dissipated in the series valve is a maximum when I_l is of such a value that the D.C. anode resistance of the valve equals the total resistance of the rectifier unit. If I_l is never large enough to give this condition then, of course, maximum power is dissipated in the series valve when I_l is at its maximum value. It is generally advantageous to employ a pentode for the series valve rather than a triode, as the anode voltage can then be made lower than the screen voltage by including a suitable dropping resistor and will be less than for an equivalent triode. Having fitted such a dropping resistor it can be used as an element in a resistor-capacitor filter for reducing hum. A dropping resistor is often needed, in any case, unless transformers are specially designed for the particular stabilizer in mind, because if any standard, or easily-available transformer is used it will generally provide more than the necessary secondary voltage.

If the current requirement is too high for a single series valve, two valves may be connected in parallel.[1,2] It might be pointed out that there is now a high-current valve available which is classed as a power amplifier in specifications. This is the CV345 (12E1) which has been found, by the author, to be admirably suitable for load currents around 200mA.

The Amplifier Design

Adequate stabilization can generally be obtained by using a single amplifier valve although Seely[3] and Elmore and Sands[4] have shown how a second stage of D.C. ampli-

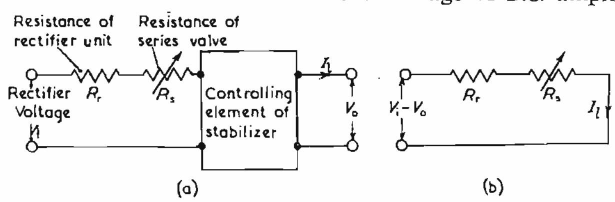


Fig. 3. Equivalent circuits of stabilizer

fication may be added to the stabilizer circuit. They have described a variety of such regulators containing two-stage resistor-coupled amplifiers, or difference amplifiers, or "cascade" amplifiers.

In the case of the conventional circuit using a single amplifier valve there are several possible connexions for the anode-load resistor R_l and these have been compared employing circuits without the additional correcting devices already described. The best-known one is the case where R_l is taken to the stabilized supply. This possesses the limitation, however, that at small grid/cathode voltages in the series valve there must be a very small current in R_l giving a low working mutual conductance for the amplifier valve. This has led to an alternative improved arrangement where the anode load is returned to a decoupled supply obtained from the unstabilized rectifier output voltage.

A better arrangement still is to return the anode load to a separate unloaded supply at a fixed voltage above the stabilized output voltage. This latter arrangement gives the most perfect stabilization of the three methods, but due to its greater complexity it is generally replaced by the second one, since adequate correction can be obtained by using the additional-correcting devices already discussed.

Other Factors Affecting Stability

The length of time over which a specified performance can be maintained from a stabilizer of this type is a further factor to be considered. Large variations in output voltage will occur if the current through the amplifier valve changes or if the reference voltage changes. The amplifier valve is generally run at quite a small percentage of its maximum specified rating (of the order of 5-20 per cent) and thus changes of the characteristics with age are found to be not very important. Major troubles may arise if the heater voltages of the valves are not constant and it may be necessary to stabilize these separately.

The amount of variation to be expected in the reference voltage when glow-discharge tubes are used has been studied in great detail by Kirkpatrick[6], Titterton[7], Cain, Clucas and the author.[8,9] In cases where a very high degree of stability is required a battery is generally used to give the reference voltage, but even this has to be used with care.[10-15].

It is also essential for best results that the components used for constructing the potentiometer across the output, which supplies the grid of the amplifier valve, are of high stability.

Performance for High-Frequency Components of Load Current

It is found that for the circuits described there is a maximum frequency which is fully amplified by the amplifier valve. This may be as low as 10kc/s. Thus, any components of the load current having frequencies greater than this maximum will not be fully regulated. The output

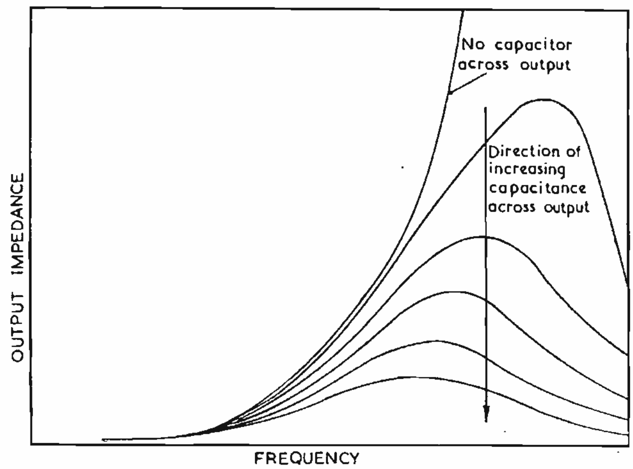


Fig. 4. Typical output impedance/frequency curves for various values of capacitance across the output

impedance is no longer the normal few ohms for these high frequencies but increases as illustrated by the typical curve of Fig. 4. Sudden changes in load present a similar problem. The trouble can be overcome by placing a capacitor across the output as can also be seen from Fig. 4. This capacitor usually needs to have a fairly high capacitance (4-16μF), the actual size depending on the maximum output impedance allowable. The impedance of the capacitor decreases with frequency and is in parallel with the output impedance of the stabilizer itself.

REFERENCES

1 BENSON, F. A. : *Elec. Eng., 21*, 200, 243 (1949).
2 BENSON, F. A. : Voltage Stabilizers. Chapter 4. *Elec. Eng.* Monograph (19 0)
3 SEELY, S. : "Electron-Tube Circuits." 309.
4 ELMORE, W. C., and SANDS, M. Electronics, 363. (McGraw Hill)
5 SCROGGIE, M. G. *Wir. Wld., 54*, 373, 415, 453 (1948).
6 KIRKPATRICK, G. M. *Proc. Inst. Rad. Engrs., 35*, 485 (1947).
7 TITTERTON, E. W. *J. Sci. Instrum., 26*, 33 (1949).
8 BENSON, F. A., CAIN, W. E., and CLUCAS, B. D. *J. Sci. Instrum., 26*, 399 (1949).
9 BENSON, F. A. *J. Sci. Instrum., 27*, 71 (1950).
10 SACK, H. : Constancy of E.M.F.'s of Dry Batteries. *Cornell University Report*, October, 1945.
11 GREENWOOD, I. A., HOLDAM, J. V., and MACRAE, D. : Electronic Instruments, 494.
12 HARRIS, E. J., and BISHOP, P. O. *Elec. Eng, 21*, 333 (1949).
13 ANDERSON, R. E. *Proc. Nat. Electronics Conference, Chicago, 4*, 315 (1948).
14 POTTER, N. M. *J. Brit. I.R.E., 9*, 61 (1949).
15 Mullard Tech. Report No. 13/1949.

The Activities and Equipment of an Industrial Electronics Laboratory

(Part 3)

By G. H. Hickling,* B.Sc., A.M.I.E.E.

IN this, and part of the final section of the series, attention will be devoted to reviewing some of the circuit techniques and design features which it has been found useful to incorporate in industrial electronic laboratory equipment and measuring devices. In the present section, standard general purpose equipment—A.C. and D.C. amplifiers of various types, wave analysers and oscillators—will be considered, with reference particularly to the requirements of accuracy in measurement.

A.C. Amplifiers

It is logical first of all to consider the requirements of a simple "straight" A.C. amplifier for general laboratory use, since this will form a basic part also of many other instruments. Such an amplifier may be used, for example, to measure the steady output of A.C. polarized position indicator devices or A.C. bridge circuits, or to display on a cathode-ray tube the output of a vibration pick-up—provided that no modification of its response characteristic is desired.

For many such applications the requirements are much more onerous than for normal sound amplification.[40,41] Amplitude response must be linear up to full output. Frequency response characteristics, to cover all likely uses, must be flat from one or two cycles per second up to the radio-frequency region—beyond which ranges either D.C. or R.F. amplifiers would be employed. Substantially zero phase shift must obtain, also, over the whole of the effective working range: but since wide-band response brings attendant disadvantages in the form of "blocking" effects and accentuation of unwanted low frequency fluctuations or high frequency "mush" (either internally or externally generated) provision for controlled cut-off at either end of the frequency range is also useful. Suggested response curves are given in Fig. 23, to be discussed later.

RC coupled circuits must almost invariably be used in wide-band A.C. amplifiers since transformers are responsible for excessive phase shift and amplitude errors at both ends of the frequency range. To obtain satisfactory stability with really low-frequency response—and also to linearize the response—the use of balanced push-pull amplification throughout the circuit, in conjunction with stabilized supplies (in mains operated equipment) is often necessary. Stabilized laboratory "power units" are now readily available for this purpose. The use of a saturable choke stabilizer for valve heater supplies has recently been proposed also, in order to take fuller advantage of improved H.T. stability.

In all electronic measuring instrument work the general principles of feedback amplifiers are, as we shall see, widely used in order to up-grade amplifier response[40,41] and to minimize the effects of valve ageing and replacement. In any universal laboratory amplifier, also, an adequate range of gain control, by means of a calibrated stepped attenuator, should be provided for. These two requirements may conveniently be met by means of a gain control which is arranged to adjust one or more negative feedback circuit, so that stability actually improves as the gain is reduced. An internal 50 cycle "check" signal may be provided so that the gain can be checked at any time against a built-in voltage divider.

A practical general purpose laboratory amplifier should provide all of these features, at least, have a voltage gain of 10^4 or preferably 10^5, and should include an output meter calibrated, with suitable range factors, in term of input voltage. A suggested output level is about 20 volts R.M.S. into, say, 5,000 ohms—sufficient for operating an indicating meter or recorder, or for supplying the separate driver amplifier of a cathode-ray oscillograph. A cathode follower input stage further increases the usefulness of an amplifier, by permitting its use with extra high impedance sources without undue loading effects,[42] while for many applications also, cathode-follower output is advantageous.

Selective Amplifiers and Wave Analysers

Amplifiers are sometimes required which will respond selectively at one frequency only. Applications which arise, in the industrial field, include sensitive detector circuits for use in carrier frequency systems, where very high gains are required and low values of signal-to-noise ratio have to be contended with: a case in point is the spectrometer amplifier to which reference was made in Part II of this series. By this technique interrupted D.C. signals of 10^{-9} volt have been detected.[43] Another common use is for frequency analysis in noise or vibration study, in which case variable frequency selective amplifiers (wave-analysers) must be used.

While inductance-capacitance type filters may be employed satisfactorily at the higher audio frequencies, and electro-mechanical filters have also been used successfully to give high selectivity in this frequency range (e.g., in a heterodyne wave analyser), current practice is to make use of resistance-capacitance frequency selective networks for the audio and lower frequency range generally. With proper design these will give both excellent selectivity and good stability.

There are various *RC* bridges which may be used,[44] of which the parallel-T circuit is the most popular. Here again the negative feedback principle is employed. Fig. 17 shows, in heavy lines, the basic parallel-T bridge network, the appropriate values of *R* and *C* for any tune frequency being indicated. This circuit must be used in a negative feedback loop of an amplifier, one of the simplest methods of connexion being as shown in the diagram. The characterestic feature of this filter is that the voltage at the output point (P) has zero value for some unique frequency *f*—the "balance" frequency of the bridge—the output being positive (i.e., having a component *in* phase with the input) at all other frequencies. In the vector diagram, Fig. 17(b), the locus of the voltage at (P) is shown for variation of frequency from zero to infinity.

With the amplifier connected as shown, negative feedback occurs, with reduction of gain to near unity, at all except the balance frequency of the bridge. Full amplifier gain is attained at this frequency only. The magnification factor of the tuned circuit (with a correctly balanced bridge) is thus equal to the inherent amplifier gain. It

* *C. A. Parsons & Co., Ltd.*

will further be noted from Fig. 17(b) that at frequencies close to resonance the feedback signal is very nearly in quadrature. Hence as the frequency passes through this value the amplifier output swings rapidly, relative to the input, from 90° lagging to 90° leading. The response near to the tune frequency is, in fact, exactly that of an ordinary *LC* tuned circuit.

Fig. 17(b) also shows (in broken lines) how the locus of the feedback signal may be changed by unbalancing the bridge, to give either a positive or a negative feedback at

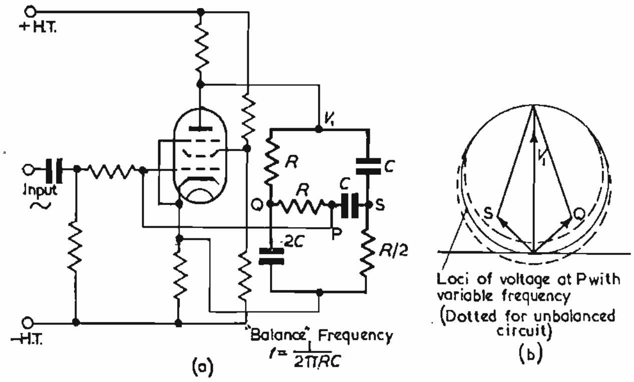


Fig. 17. (a) Selective amplifier stage using parallel-T filter. (b) Vector diagram for filter response

tune. Judicious use of the former effect can be made to *increase* the amplifier gain at resonance, and hence to increase the effective selectivity—or even, if desired, to render the circuit oscillatory.

Since the parallel-T circuit comprises only resistors and capacitors, it lends itself to the construction of very compact fixed frequency filters which may conveniently be made up as plug-in units, thereby enabling a standard amplifier to be used, when required, for selective response at any desired frequency.

Wave Analysers

The frequency law of the *RC* frequency selective filters — $f = \frac{1}{2\pi RC}$ — is well suited, to their use in variable-tuned amplifiers, or wave analysers. Either *R* or *C* may be varied (or both) and the direct reciprocal relationship results in a much greater proportionate frequency change for a given change in capacitance, say, than occurs in an *LC* tuned circuit for which the inverse square-root law applies. In a wave analyser using the parallel-T circuit a 3-gang resistance unit may be used for normal fine adjustment of frequency, while range changing is effected by capacitance switching. This arrangement permits a wide total range of frequency variation with only a limited variation of load impedance on the amplifier. A wave analyser of this type has the considerable advantages over the heterodyne type that selectivity remains constant (though adjustable) for all frequencies, and also that an output is available at the tuned frequency so that it can be used to give audible indication by means of a loudspeaker.

In order to obtain still better selectivity, a worth-while refinement of the parallel-T filter circuit is available in the 8-element modified Scott bridge.[44] In this circuit, Fig. 18, the centre arm is split into two parallel portions, together having the same impedance as in the original bridge, but with the *C* and *R* components in one case interchanged. Since the impedance between points Q and S remains unaltered, and as the elements in the arm QPS have the same relative values as before, the terminal P still gives a null output at the balance frequency, with an in-phase signal for negative feedback at all other frequencies. The mid-point T of the second branch, however, gives a *maximum* output at the tune frequency (Fig. 18(c)) falling to zero at frequencies remote from this value. Thus by taking the output signal from this latter point the overall selectivity of the analyser is enhanced. Actual relative response curves are given in Fig. 18(b). Fig. 19 shows, in somewhat simplified form, a practical circuit in which the advantages of this type of filter may be realized. The use of cathode-followers both to feed into the comparatively low impedance of the filter network, and to take output signals from the terminals P and T without loading, will be noted. A further feature of the circuit is that the number of *CR* couplings round the feedback loop is restricted to two, this condition being necessary in order to preclude any possibility of low frequency oscillation or "motor-boating" when using a high overall gain.

A different type of wave filter, it may be noted here, has been found useful for the purpose of making noise surveys, where, it is desired not so much to determine the precise *source* of the noise—which may be unavoidable—as to devise measures for reducing it by external absorbers, etc. This comprises a series of wide-band-pass filters which, when used with a standard sound-level meter (having itself an appropriately "weighted" response corresponding to that of the human ear), will enable the distribution of total noise to be measured in, say, eight bands covering the audio spectrum. Such a unit may conveniently be made in portable form, using *RC* feedback filters[45] designed to give high-pass and low-pass response with appropriate cut-off frequencies.

RC Oscillators

It has already been hinted that *RC* filter networks lend themselves to the design of low frequency oscillators. For this specific application, however, the somewhat simpler Wien Bridge circuit (Fig. 20) has found greater popularity than the parallel-T, since only two variable elements are needed. This circuit gives a *positive* (in phase) signal at balance, from the output point P, which may thus be connected to the input grid of a 2-stage amplifier, as shown. This signal falls to zero at high or low frequencies. Constant negative feedback is provided by the resistance divider R_1R_2 constituting the second half of the bridge, this ratio being adjusted so that just sufficient positive feedback occurs at tune to maintain oscillation. Resistance R_2 may consist of a low wattage filament lamp as a non-linear element for the purpose of providing automatic amplitude control. Alternatively a resistor of

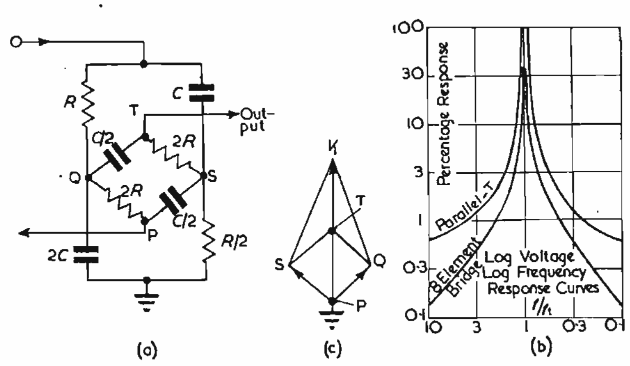


Fig. 18. (a) 8-Element bridge circuit. (b) Relative response curves. (c) Vector diagram

the thermistor type can be used for the same purpose in position R_1 with the advantage that a lower power dissipation is required.

It may be noted in passing that the Wien Bridge circuit lends itself equally well to the design of analysers. One recent instrument makes use of two such filters in cascade to give good selectivity, the alignment of the two being adjustable to provide a measure of band-pass response combined with a very high maximum selectivity.

Decade Tuned Oscillators

The principle of the decade tuned oscillator, in which the desired frequency can be directly set on dials in a manner analogous to that of adjusting an ordinary decade resistance box, is basically simple, being dependent on the fundamental frequency law of the *RC* tuned oscillator:

$$f = \frac{1}{2\pi RC}$$

Either resistance or capacitance switching may be used for frequency adjustment, the former being generally preferable. Considering this case first, it follows from the elementary expression for parallel connected resistors:

$$1/R = 1/R_1 + 1/R_2 + 1/R_3 + \ldots$$

that if several paralleled resistors (or banks of switched resistors) are used to make up each "*R*" in a frequency-selective bridge network the resulting frequency will be:

$$2\pi f = \frac{1}{R_1 C} + \frac{1}{R_2 C} + \ldots$$

Hence if any one of the paralleled resistance units is varied the *incremental* frequency change will be independent of the value of any of the others. It is thus clearly possible to make one switched resistance bank vary the frequency in, say, hundreds of cycles per second, while a second parallel connected bank is arranged to give frequency variation in tens, and a third in units. The individual resistance values in each bank, in reciprocal relationship to the digital values of the steps, are readily calculated from the general frequency expression given. In any one bank, as a matter of convenience, resistance values are normally built up by connecting suitable elements in series, but it should be noted that the correct result would be obtained if from one to ten resistors of *equal* value, in any one decade, were switched into circuit in parallel. Zero on each dial corresponds, of course, to an open circuit. Corresponding resistors in successive decades are in 10:1 ratio.

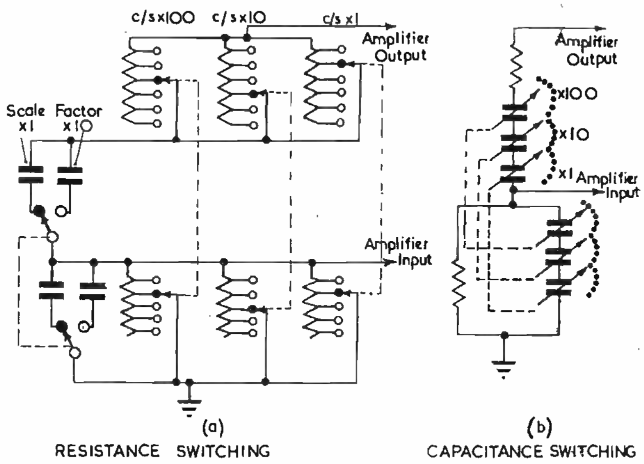


Fig. 21. Decade oscillator frequency control circuits
(a) Resistance switching. (b) Capacitance switching.

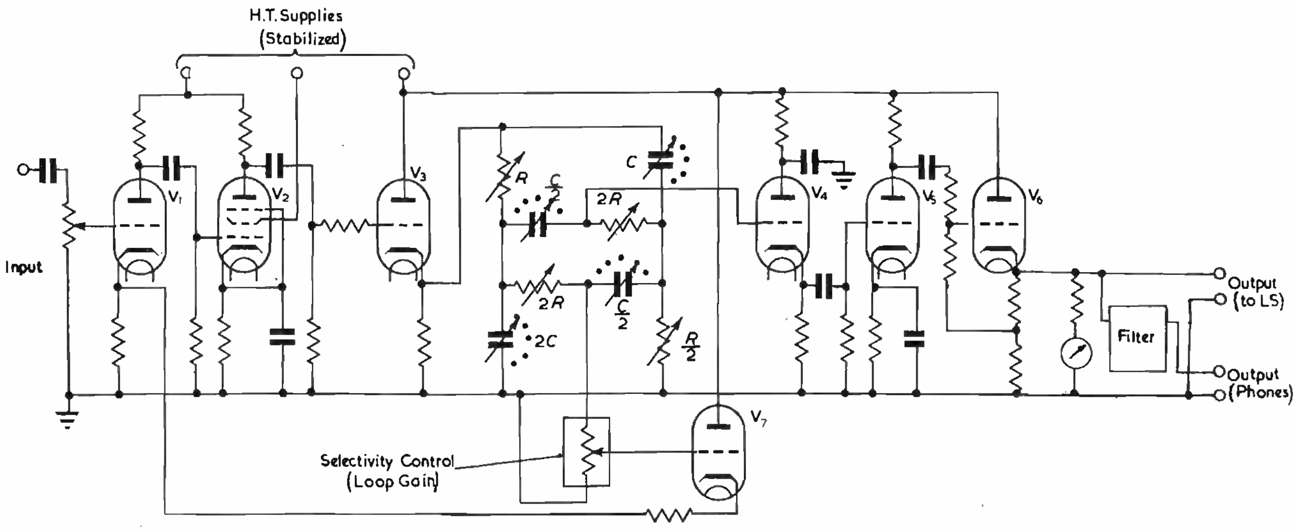


Fig. 19. Practical wave analyser circuit (simplified)

Fig. 20. Wien bridge frequency-selective filter as oscillator circuit

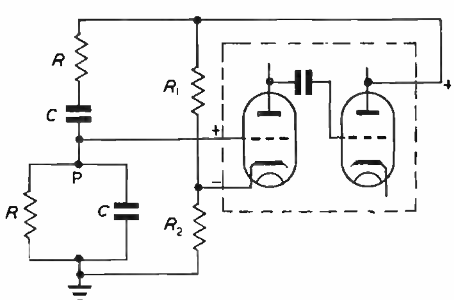


Fig. 21(a) shows the detailed circuit arrangement required for a 3-dial resistance tuned decade oscillator. The third dial (comprising the highest value resistances) may consist of decade switched banks, as for the first two, or may be a suitable two-gang continuously variable potentiometer in order to give smooth control of frequency between steps on the second dial. A further useful device which can be employed, as shown in this diagram, is to switch the capacitors in the circuit also, in 10:1 ratio steps, so as to give "scale factors" of unity, ten, a hundred, etc., on the frequency values shown by the resistance dials: thus the same circuit will give 1 – 1,110 cycles in 1c/s steps, 10 – 11,100 cycles in 10c/s steps, and so on.

The corresponding circuit arrangement for a switched capacitance decade oscillator would be as shown in Fig. 21(b). In this case the banks of capacitors are connected in *series* since the resultant value of series connected capacitors (as for parallel resistors) is:

$$1/C = 1/C_1 + 1/C_2 + 1/C_3 + \ldots$$

In this case, also, it would be convenient to make up each individual decade from 10 equal capacitors in *series*, the selector switch being arranged to contact each interconnexion point in turn. The main disadvantage of the capacitance tuned arrangement, apart from the difficulty of procuring the necessary numbers of accurately adjusted capacitors, is that the decade which influences the frequency to the greatest extent comprises the smallest value capacitors, in which accuracy is most difficult to attain. By the same token, incidentally, the most important bank in a resistance switched decade oscillator comprises the *lowest* value resistors which can therefore be of the precision wire-wound type.

It is necessary to insert here a warning that, if accuracy of calibration is to be achieved in a decade oscillator, special attention must be paid to the design of the amplifier—particularly as regards phase shifts and matching to the *RC* filter. It may be noted, too, that although only the parallel-T and Wien bridge circuits have been described, these are not the only *RC* networks available for use in oscillators. The simple "phase shift" circuit is widely used and the bridged-T network (a simplified variant on the parallel-T) has also been made the basis of a wide frequency range oscillator.[46]

Integrating Amplifiers

The processes of integration and differentiation with respect to time—together with other mathematical transformations—occur in various automatic computing problems.[32,47] More everyday instances of the use of integrating amplifiers occur, however, in connexion with vibration detectors of the velocity or acceleration response types, when it is desired to convert the indication to displacement or (in the latter case) to velocity response. The moving-coil vibration pick-up with a heavy, low natural frequency, suspension system comes into the former category, while the usual type of inertia operated piezo-crystal pick-up is of the latter type.

True integration down to zero frequency in any electronic amplifier is, from a practical standpoint, impossible, since to obtain the integral of any D.C. input quantity over a period of time would, in effect, require infinite D.C. output from the amplifier. In the A.C. range, above any specified minimum frequency, however, integration can be effectively obtained—most simply by the introduction of a simple *RC* lagging exponential time-constant into the circuit—Fig. 22(a). Theoretically we have:

$$\int E \, . \, \sin \omega t = -E/\omega \, . \cos \omega t$$

i.e., the required output for a given constant amplitude

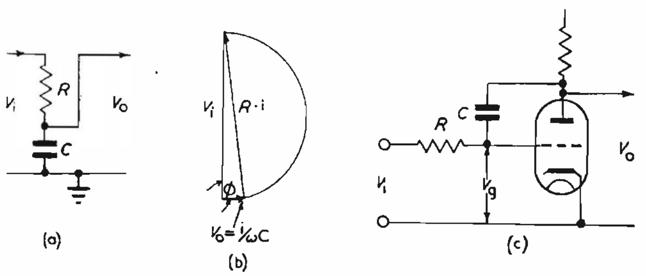


Fig. 22. Integrating RC networks

(a) Simple RC circuit. (b) Vector diagram for (a). (c) Miller integrator.

sinewave input signal should be inversely proportional to frequency while phase shift remains constant at 90° lagging. This holds true, sufficiently for most practical purposes, in the case of the simple *RC* circuit, provided that the voltage attenuation at *minimum* frequency is not less than about 10:1 (see Fig. 22(b).

A disadvantage which follows from this last condition is that, for an *RC* integrator to operate over a wide range of frequencies, the output signal level at the maximum frequency limit is necessarily very small and difficulties arise in avoiding spurious pick-up or noise voltages—input signal level being limited by the previous amplifier stage. Here, however, the negative feedback principle again comes to our assistance, in the form of the Miller integrator[48] (Fig. 22(c)) which comprises an amplifier with simple negative capacitance-feedback. The theory is simply

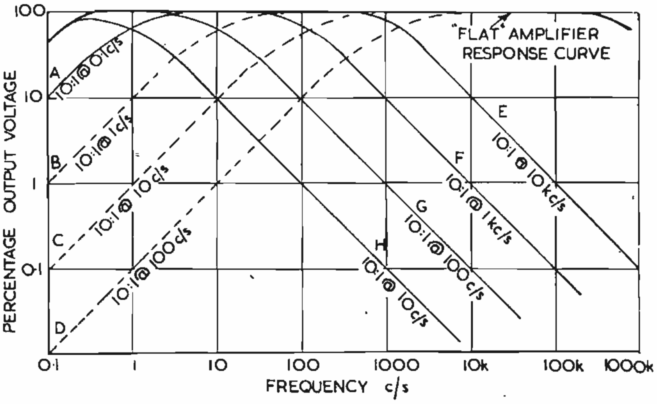


Fig. 23. Frequency response characteristics for general purpose amplifier with various integrating and differentiating time-constants

explained on the assumptions that $i_g = 0$ and that v_g is small relative to both V_i and V_o. On this assumption, since the currents in R and C must be equal:

$$V_i/R = -j\omega C V_o,$$

$$\text{or } V_o = \frac{V_i}{-j\omega RC}$$

The response thus complies with the conditions for true integration provided that the valve gain is high, and so long as the inequality $v_g \ll V_i$ remains true: but at very low frequencies, when C becomes ineffective, V_g approaches the value V_i and the relation therefore no longer holds. In this respect the response of the Miller and the simple *RC* integrators is the same.

The converse process of differentiation, which finds useful practical application in pulse sharpening circuits, etc., is very simply obtained by shortening the time-constant of the normal *CR* coupling in an amplifier so as to give the required discrimination against low frequencies.

It is not always appreciated that integration and differentiation characteristics are equivalent simply to high and low frequency cut-off, respectively, in the frequency response characteristic of the amplifier, as produced by simple *RC* time-constants.[47] It is consequently unnecessary to regard these as characteristics of special purpose amplifiers; they should rather be built in to any general purpose laboratory amplifier, suitable switching arrangements being incorporated, as previously suggested, to enable any desired time-constant—integrating or differentiating—to be selected, as indicated in Fig. 23.

Applications requiring double integration (i.e., a voltage attenuation of two decades per decade of frequency), as for conversion from acceleration to displacement response, can be met either by including two integrating amplifiers in the same unit, or by cascading two separate single integrating amplifiers. A special vibration amplifier providing the former facility is shown in Fig. 24.

Since any integrating amplifier inherently gives increased gain at frequencies somewhat below its working range, the requirements of low frequency stability, as discussed under "A.C. Amplifiers", are especially necessary. Where double integration is provided this assumes still greater importance.

Phase Discriminators

Rectification of the output of an A.C. amplifier, to give a demodulated or D.C. output signal, is a common requirement when using A.C. excited bridge circuits or A.C. polarized detector devices. In such cases the ability of an amplifier to give phase discrimination—or reversal of output polarity with reversal of phase of the input signal—has marked advantages, particularly as regards zero stability. Such an amplifier may be used as a true nul detector and gives unambiguous indication of the sense of unbalance in an A.C. bridge circuit. In a strain gauge bridge "zeroed" at zero strain, for example, tensile and compressive strains are reproduced with appropriately reversed polarity. The bridge or detector device may be in balance at the mid-point of the range of measurement (the reference zero position) with zero signal in the amplifier, so that zero drift due to changes of A.C. voltage or amplifier gain is eliminated, while response up to the full signal capacity of the amplifier may be obtained on either side of zero.

Several possible forms of discriminator circuit are available, of which that shown in Fig. 25(a) is one which well illustrates the principle. The A.C. voltages applied to the two rectifiers forming the demodulator proper are equal to the vector sum and difference of the amplified signal voltage (V_1) and the constant amplitude reference voltage (V_2). The output, being the difference between the two rectified voltages, thus reverses in polarity as the signal reverses from in-phase to out-of-phase with respect to the

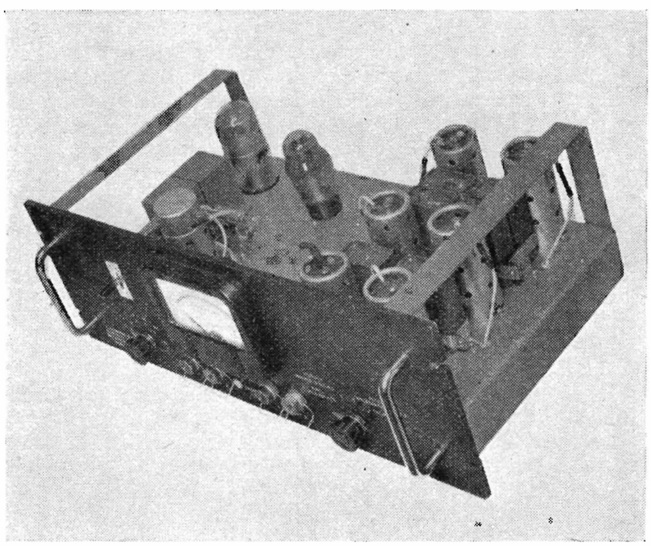


Fig. 24. Vibration amplifier (double integrating)

(Direct reading in "inches × 10^{-3}", "inches/second" or "inches/second/second")

reference signal. Its amplitude is proportional to the in-phase (or anti-phase) component of the input signal; but the circuit has the further advantage, for some applications, that it discriminates strongly against any quadrature component of the input, since the voltages applied to the two rectifiers are equal and cancel out when $+V_1$ and $-V_1$ are at 90° to V_2. This feature is particularly useful for example in A.C. bridge networks involving complex impedances (of which an instance will be given later) where the capacitance balance, say, must be unaffected by the resistance balance.

Another phase discriminating amplifier circuit shown in Fig. 25(b), in which the reference signal is supplied as an A.C. anode voltage (to valves V_1 and V_2), has been usefully applied to a velodyne servo system. In this case the servo motor speed is controlled by applying a D.C. feedback voltage, derived from a tacho-generator, across the valve cathodes. A similar principle is employed in the electronic temperature controller referred to in Part I.

In measurement circuits where the demodulated output is itself an A.C. signal it will generally be applied to the deflecting terminals of a cathode-ray or other oscillograph, while outputs which are substantially D.C. will usually be supplied to an indicating meter or chart recorder. Final output stages will consequently vary somewhat to meet these requirements.

D.C. Amplifiers

So far only circuits involving A.C. amplification have been considered. There are, however, a number of important applications in the field of measurements calling for the use of D.C. amplifiers. Measurements with thermocouples or thermopiles, photocells and, if D.C. energized, resistance strain gauges fall into this category, whenever the limitations of the simple galvanometer are inacceptable. They are used, too, in various "carrier" type equipments and also play an important part in the design of D.C. voltage stabilizers, although probably the most onerous requirements—which have greatly stimulated development work in this field—arise in electro-medical research. Direct coupled driver amplifiers for cathode-ray oscillographs, also, are desirable—to be used with either D.C. or A.C. pre-amplifier units as required.

The over-riding difficulty in the design of high gain D.C.

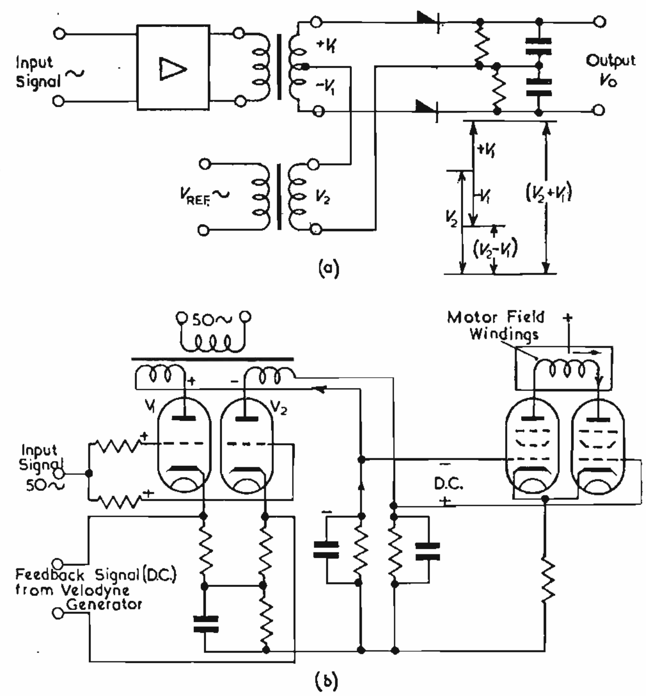


Fig. 25. Phase discriminating amplifier circuits

amplifiers—apart from the inconvenience of the progressive rise in D.C. potential normally incurred in successive stages—is that of zero drift, and the main features of all successful D.C. amplifier designs are the outcome of attempts to minimize this effect.

From the practical standpoint D.C. amplifiers fall into two categories (with one design which may be said to be a hybrid between the two). These are the purely thermionic amplifier, with the same upper frequency limits as the normal *RC* coupled amplifier, and the electro-mechanical type in which some mechanical device—either an interrupter, a vibrating capacitor, or a galvanometer element—is employed in the input stage as a comparator or error-detector in a feedback circuit. Fundamental considerations affecting the performance of valves appear to limit the ultimate stability of the thermionic class to a little better than 100 microvolts at the input. Drifts of this order over any reasonably long time interval are unavoidable owing to changes of grid-cathode potential analogous to those causing "noise" in A.C. amplifiers.* Feedback, while effective in overcoming drifts occurring in later stages of amplification, provides no complete cure since a thermionic valve must be used as the ultimate means of comparison between the input and feedback signals.

An entirely different order of performance is obtainable from the "*electro-mechanical*" *class* of D.C. amplifier—at the expense, unfortunately, of A.C. response above a few cycles per second—since the foregoing limitation is removed. Any of the three main types in this latter category may be represented functionally by the block diagram given in Fig. 26. A large measure of negative feedback is employed, the comparator device being used to detect the error signal only, between the feedback and input voltages. In the interrupter type of amplifier a high speed carpenter relay, operating at say 50c/s, is used to convert this error signal to A.C. Transformer coupling is used to feed this signal into a normal A.C. amplifier—preferably selective to the "chopper" frequency. The output is then phase-sensitively rectified and fed as D.C. through the load and the feedback resistance, in series. The polarity is such that the drop in the latter opposes the input voltage, so tending to eliminate the error signal. Although the actual input impedance of the comparator device may be fairly low, the apparent D.C. input impedance of the amplifier is thus much higher, increasing with the amount of feedback to some 50,000 ohms. The effects of valve noise in this type of amplifier are effectively eliminated by restricting its response to a single frequency. Stabilities attained in an actual commercial instrument, over long periods, are under 1 microvolt.

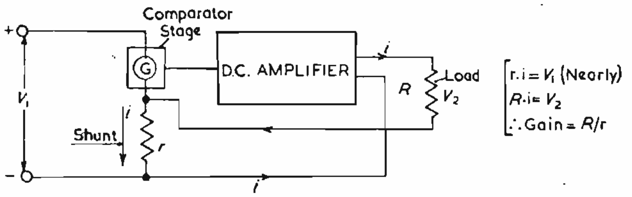


Fig. 26. Schematic diagram of D.C. amplifier with feedback

Where the input impedance of this last type of amplifier, notwithstanding feedback, is too low, a similar principle may be used in the vibrating reed electrometer amplifier which has been applied to the measurement of ionization chamber potentials and also in biological work.[50] In this case again the D.C. error voltage applied to the vibrating capacitor generates an A.C. signal for amplification.

The "galvanometer-photocell" type of amplifier[51] is also functionally identical to those just described. The comparator device comprises a robust reflecting galvanometer arranged to control the relative intensity of illumination of two photocells, the differential output from these being fed to a D.C. amplifier controlling the current in the load. Negative feedback is used to stabilize the response in precisely the same manner as already described.

The hybrid type referred to above combines a direct coupled thermionic amplifier, having a good frequency response, with an auxiliary feedback amplifier of the interruptor type to correct continuously for any drift of zero.

In the design of purely *thermionic* D.C. *amplifiers* the principal methods used to avoid zero drift are:—

1. The use of balanced circuits.
2. Stabilized supplies.
3. Specially selected valves—(both types and where necessary individual valves).

So far as circuits are concerned the methods used to obtain stability are closely connected with the method of stepping up the cathode potential, as is normally required, between stages. Current practice generally favours the completely balanced circuit as illustrated in Fig. 27(a). The common cathode resistance for the two valves (or half valves) comprising each stage results in a high degree of discrimination against unbalanced signals, thereby giving the circuit a large measure of immunity from drifts due to supply voltage changes. Phase splitting, with unbalanced input occurs automatically. At the same time, by suitable choice of cathode resistor values, the appropriate D.C. potentials for each stage are obtained, without, of course, any loss of gain due to negative feedback. Furthermore, as the signal components of the two anode currents cancel one another out, no variation in total H.T. current occurs with change of signal voltage, so removing a possible cause of instability.

A number of other D.C. amplifier circuits have been published from time to time,[52-56] three, which are of some interest, being included in Fig. 27(b) to (d). That shown in simplified form in Fig. 27(b) provides the basis of a convenient C.R.O. driver amplifier.[52] The metered variable voltage supply to g_2 affords a calibrated shift control,

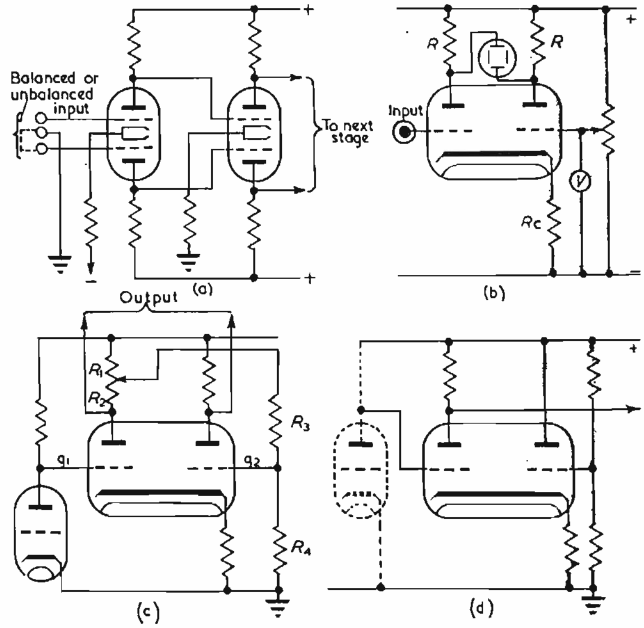


Fig. 27. Basic D.C. amplifier circuits

(a) Balanced circuit. (b) Direct coupled C.R.O. *driver amplifier. (c) Phase invertor double triode stage. (d) Cathode coupled double triode stage.*

giving a measure of the D.C. level of the voltage under investigation (for zero oscillograph deflexion) at the same time enabling the scale value on the screen to be determined. In this way waveforms greater than full screen amplitude may be investigated in considerable detail.[53]

The "phase invertor double triode stage"[52] shown in Fig. 27(c) provides a convenient means of coupling from an unbalanced input stage to give balanced output, with the advantage (as compared with the previous circuit) of maintaining the full stage gain available from the valve. The requisite input voltage for g_2 (in anti-phase to g_1) is derived from the anode circuit of the first half valve: suitable choice of the ratios R_1/R_2 and R_3/R_4 enables both the mean D.C. and the A.C. or signal potentials of the two grids to be balanced so that balanced anode currents are obtained, with no A.C. potential on the cathode.

Fig. 27(d) shows a further variation on the same theme in the "cathode coupled double triode stage."[54] Here the second grid of the double triode is held at a fixed D.C. potential, this half of the valve being used as a cathode-follower so that it effectively fixes the cathode potential at a value to suit the desired operating potential of the previous stage. Here the loss of gain due to feedback is

* *(Attempts to differentiate between "drift" and "noise" have, in fact, led to the conclusion[49] that it is preferable to regard these two effects, from whatever cause they arise, as synonymous.)*

actually equivalent to doubling the anode impedance of a normal single triode with decoupled cathode. The arrangement has been made use of in a D.C. voltage stabilizer. It has the incidental advantage that when required, by simply interchanging the grid connexions to the amplifier and cathode-follower sections of the valve, the normal 180° phase reversal can be avoided, the stage then giving an output signal in phase with the input.

By economizing in anode to cathode drops in the early stages, it is possible to employ several direct coupled stages, with any of the methods just described, using only a limited H.T. supply voltage. Nevertheless it is a material advantage in designing such an amplifier to be able to drop the D.C. potential between successive stages. This may be done (without recourse to batteries) by the use of the screen-coupled cathode follower stage in which the screen to cathode drop of a tetrode or pentode valve is utilized.[52] Low values of anode and screen current must be used to avoid excessive load on the preceding stage, but with a suitable valve a drop of about 250 volts between stages can be obtained in this manner. Using this technique it is possible to design a satisfactory 3-stage D.C. amplifier having the same quiescent potential at input and output terminals.

The principle of converting D.C. signals to A.C. for the purpose of amplification (other than by electro-mechanical methods) has also been widely exploited,[56] although where this is done by electronic valve circuits, the previously noted limitation on zero stability remains.

The circuits which we have so far considered are those of general-purpose instruments which may be said to form the backbone of our laboratory equipment. In the following and final section some more specialized instruments will be referred to, and in particular a number of circuits used for measurements with capacitance type detector devices will be described. The more general requirements of laboratory equipment—construction and standardization—will also be considered.

REFERENCES

[40] ZAALBERG VAN ZELST, J. J. : *Philips Technical Review*, *9*, 25 (1947).
[41] Methods of Applying Negative Feedback—A Reference Chart. *Electronic Eng.*, *17*, 770 (1945).
[42] BISHOP, P. O. : A High Impedance Input Stage for a Valve Amplifier. *Electronic Eng.*, *21*, 469 (1949).
[43] AIKEN, C. B., and WELZ, W. C. : D.C. Amplifier for Low Level Signals. *Electronics*, 124 (Oct. 1947).
[44] YATES, H. G. : Non-inductive Wave-analyser Circuits of Constant Q. *Engineer*, *181*, 515 (1946).
[45] MILLER, H. C. : *RC* Amplifier Filters. *Wireless Engineer*, *27*, 26 (1950).
[46] SULZER, P. G. : Wide Range *RC* Oscillator. *Electronics*, 89 (Sept. 1950).
[47] BELL, D. A. : Reactive Circuits as Computors and Analogues. *Electronic Eng.*, *22*, 232 (1950).
[48] BRIGGS, B. H. : The Miller Integrator. *Electronic Eng.*, *20* (1948).
[49] BISHOP and HARRIS : A D.C. Amplifier for Biological Applications. *Rev. Sci. Inst.*, *21*, 366 (1950). (This article contains also a good review of the literature of D.C. amplifiers.)
[50] BLÜH and SCOTT : Vibrating Probe Electrometer for the Measurement of Bio-electric Potentials. *Rev. Sci. Inst.*, 867 (1950).
[51] GALL, D. C. : A D.C. Amplifier for Industrial Measurements. *J.I.E.E.*, *89*, Pt. II, 434.
[52] YU, Y. P. : Cathode-follower Coupling in D.C. Amplifiers. *Electronics*, 99 (Aug. 1946).
[53] MANSFORD, H. L. : The Waveform Monitor. *Electronic Eng.*, *19*, 272 (1947).
[54] WILLIAMS, E. *Electronic Eng.*, *16*, 509 (1944).
[55] VAN SCOYOC and WARNKE : A D.C. Amplifier with Cross Coupled Input. *Electronics*, 104 (Feb. 1950).
[56] LAMPITT, R. A. : D.C. Amplifier using Modulated Carrier. *Electronic Eng.*, *18*, 347 (1946).

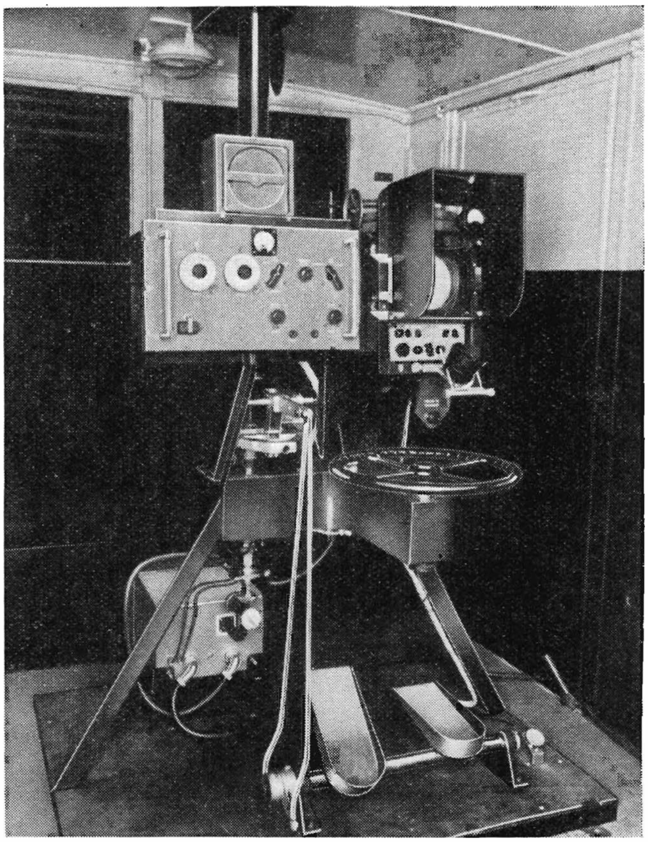
A New Radar Approach System

Details have now been released by E. K. Cole, Ltd., of a new simplified radar approach the basis of which is the combination of a 3 centimetre radar installation with a V.H.F., D.F. receiver, the radar dish being mounted on a common rotatable shaft with the D.F. aerial. The radar dish is independently controllable in elevation but it is permanently coupled to the D.F. aerial in azimuth. The radar display is a simple "A" scope presentation calibrated in nautical miles. Two scales are arranged to show the elevation angle of the radar dish and the azimuth angle of the D.F. aerial and radar dish. A series of adjustable contacts, operated by cams on the scale-drives illuminate lamps mounted adjacent to the "A" scope to indicate when the aircraft is within prescribed narrow limits of the desired course while, if the limits are exceeded, the appropriate instruction such as "Aircraft Turn Left/Turn Right" is illuminated. The necessary approach instructions are conveyed to the pilot by means of a separate V.H.F. installation. A visual indication of the D.F. aerial null position is provided in the form of an audio meter mounted beside the azimuth scale.

The equipment is designed for installation in either a permanent building or a trailer. A metal framework bolts to the floor to support the radar installation and the D.F. receiver, this framework also supports the bottom bearing of the aerial shaft and carries the azimuth and elevation controls.

The radar transmitter has a peak power output of 10kW and operates in the "X" band. It has a circular beam width of 3° at half-power points. The D.F. receiver is crystal controlled and operates between 100-156Mc/s.

A pilot using the approach aid is told to fly at 2,500ft. and brought to within radar contact by means of the V.H.F., D.F. equipment. The aircraft is then turned through 90° for identification and given a new course to bring it on to the down wind leg of the approach pattern, the pilot is then told to reduce height to 1,500ft. A further 90° turn then brings the aircraft on to the base leg, this is followed by a 40° turn which brings the aircraft to a point from which the final approach is made. From this point the pilot is "talked down" to a "gate" at a height of 250ft. and half a mile from touch-down, he is then given a new heading for the runway and told to make a visual landing.



The controls of the latest version of the Ekco radar approach. The azimuth control is in the form of a large hand-wheel while the foot-pedals control the elevation of the radar dish.

Two Bridges for Measuring Valve Parameters

By G. Smith,* B.Sc.

THE calculation of valve circuits requires a knowledge of the valve parameters; anode impedance (r_a), mutual conductance (g_m) and amplification factor (μ). These parameters can be obtained from the static characteristics of the valve, measured as the change of current or voltage as another voltage is varied, or measured by a bridge. The author has had occasion to use the parameters in connexion with calculation of amplitude in phase-shift oscillators, in which the variation of parameters is important, and has found bridges are the only satisfactory method of measuring them. The first two methods give only an average value over the range and do not give accurate results when the parameters are varying rapidly. Moreover, provided the design is good and the effects of stray capacitances are small or can be calculated, the accuracy of the bridge is improved to the limit of the components or to its sensitivity. The bridges described here permit the use of a power pack without having to consider its impedance or its capacitance to earth, and measure g_m, r_a and μ. They represent a practical advance on the usual valve bridges by permitting the use of a power pack instead of batteries.

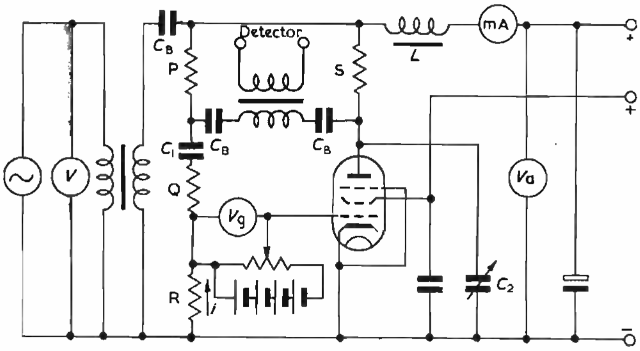


Fig. 1. Bridge for measuring μ and r_a

The Valve Equation

Although the valve is essentially a non linear device, only the first order terms of the Taylor expansion need be considered if the A.C. voltages applied to the valve electrodes are small, and the equation can be written

$$\partial i_a = 1/r_a\ (\partial V_a - \mu \partial V_g) \quad \text{.......... (1)}$$

That the two constants are r_a and μ follows from the definitions

$$\partial i_a/\partial V_a = 1/r_a \text{ the anode conductance} \quad \text{.......... (2)}$$

$$\partial i_a/\partial V_g = g_m \text{ mutual conductance} \quad \text{.......... (3)}$$

$$\partial V_a/\partial V_g = +\mu \text{ amplification factor} \quad \text{.......... (4)}$$

It follows from the definitions that knowing two parameters the third is obtained from the relation

$$g_m r_a = -\mu \quad \text{.......... (5)}$$

* Formerly William Siemens laboratory, King's College, London.

The Bridges and their Balance Equations

Valve bridges are complicated by the need for D.C. supplies. In most bridges the impedance of a power pack and its high capacitance to earth would upset the balance equation and so batteries are used. Two bridges here described are so designed that a power pack can be used. In addition they give a common earth to the A.C. and D.C. supplies and the valve cathode; only one resistance box carries D.C.; and the two bridges together measure g_m, r_a and μ and are easily derived from each other.

The circuits of the bridges are shown in Figs. 1 and 2. In calculating the balance equation the valve is replaced by a voltage V_a. From Equation (1)

$V_a = r_a i_a + \mu V_g$ and taking the direction of the current through R in Fig. 1 as positive

$V_a = r_a i_a - \mu i R$ where i is the total current in R.

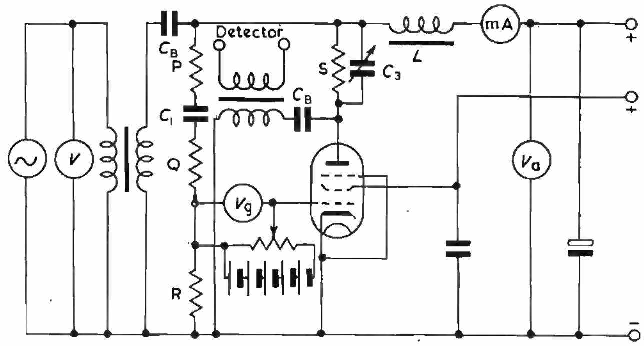


Fig. 2. Bridge for g_m

The balance equations for Fig. 1 are

$$r_a\ (Q + R) = \frac{1}{\omega^2 C_1 C_2} \quad \text{.......... (7)}$$

$$S\ (Q + R(1 - \mu)) = r_a P - r_a \frac{SC_2}{C_1} \quad \text{.......... (8)}$$

Substituting for C_2 in (8)

$$S \left\{ Q + R\,(1 - \mu) + \frac{1}{\omega^2 C_1{}^2 (Q + R)} \right\} = r_a P \quad \text{...... (9)}$$

If $\omega = 2\pi \times 10^3$, $C_1 = 2\mu F$ and $Q + R > 1{,}000\Omega$

$$r_a P = S\,(Q + R\,(1 - \mu)) \quad \text{.......... (10)}$$

to within 1 per cent.

If $R = 0$

$$r_a = Q'S/P \quad \text{.......... (11)}$$

If $R \neq 0$

$$R\,(1 - \mu) = r_a P/S - Q = Q' - Q$$

$$-\mu = \frac{Q' - Q}{R} - 1 \quad \text{.......... (12)}$$

S can be fixed at 1,000 ohms and this will cover most measurements. Q and C_2 are varied to obtain balance.

The essential condition to use the simplified Equations (11) and (12) is that Q must be greater than 1,000 ohms when the frequency is 1,000c/s.

Fig. 1 will measure r_a and μ but the most important region of the pentode has very large values of each and the resulting quotient g_m is not accurate. Fig. 2 measures g_m directly and the balance condition implies that $\partial V_a = 0$.

The balance equations are

$$(P + Q + R)S = 1/\omega^2 C_1 C_3 \quad (13)$$

$$g_m RS = P + Q + S - SC_3/C_1 \quad (14)$$

Substituting for C_3 in (14)

$$g_m = (P + Q + R)/RS \quad (15)$$

to within 1 per cent provided $P + Q + R > 1,000$ ohms, If $P + Q = 1,000$ ohms and $S = 1,000$ ohms, then the range $g_m > 1,000\mu$mhos is covered.

The Effect of Stray Capacitance

The stray capacitances that concern us are

(a) Anode-cathode capacitance,
(b) Anode-grid capacitance,
(c) Detector-earth capacitance.

(a) In Fig. 1, provided it is not too large it is added to C_2. If it is larger than C_2 given by the Equation (7) then a capacitor is needed across S, but this may modify the equation seriously. In Fig. 2, it does not alter the balance equation.

(b) The anode grid capacitance is never more than a few picafarads and as such has negligible effect on the equations.

(c) Detector-earth capacitance exists on both sides of the detector. On one side it is added to the anode-cathode capacitance and the remarks of (a) apply; on the other side it can affect the balance by a few per cent if it is more than 100pF, in Fig. 1, but has no effect in Fig. 2. To minimize this capacitance a well screened transformer with low capacitance from primary to earth is required.

Experiments with a CV1136

The CV1136 is a H.F. pentode having a variation of r_a between 2kΩ and 5MΩ, of g_m between 0·5 millimhos and 10 millimhos and of μ between 1 and 5,000. It is, therefore, suitable as a means of testing the bridge over wide limits. It is well nigh impossible to repeat the D.C. voltages on the valve electrodes with sufficient accuracy to expect every point to lie within the small margin of error; but by plotting the curves of $1/r_a = g_a$ against V_a and of g_m against V_g and integrating with a planimeter the curves of i_a against V_a and V_g were predicted and were shown to agree closely with the static curves.

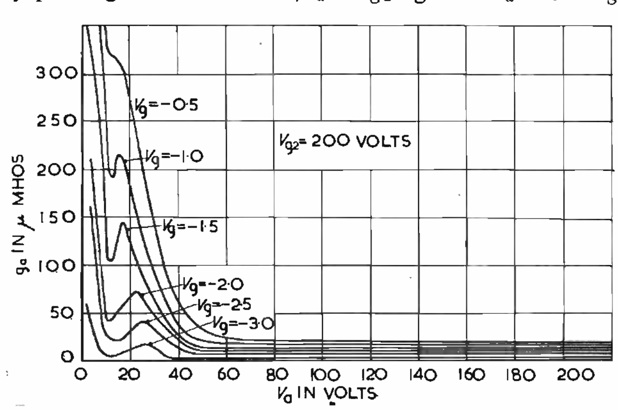


Fig. 3. Output conductance characteristics of the CV1136

The A.C. source was a B.F.O. connected to the bridge by a step-down transformer with a voltmeter connected across the primary. The blocking capacitors C_B were each 2μF and the choke L, introduced to prevent an A.C. short, was 10 henries. The resistors P, Q, R and S were non-inductive dial boxes. C_1 was a 2μF capacitor and C_2 was variable between 10pF, and 3,000pF. For Fig. 1, the input transformer ratio was 4:1 and the voltage applied was 0.1 volts at low V_a up to 10 volts at high V_a (where the percentage change in r_a and μ is small). The maximum A.C. voltage applied to the grid was 0·01V R.M.S. S was set to 1,000 ohms and in setting the D.C. voltage on the anode, allowance was made for the voltage drop in this resistor. All experiments were carried out with V_{g2} = 200 volts.

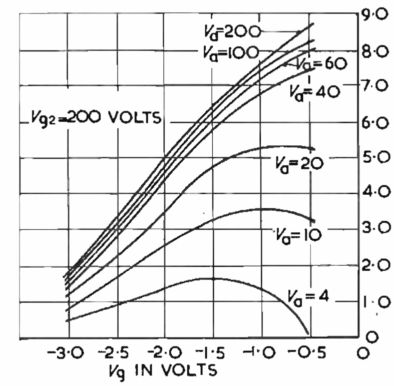


Fig. 4. Mutual conductance characteristics of the CV1136

Results of Experiments

The curves plotted from these readings are of $g_a = 1/r_a$ against V_a and show the way in which this method can follow rapid changes of the parameters. Integrating these curves give the values of i_a indicated by circles in Fig. 5.

In the bridge of Fig. 2 the input transformer ratio was 10:1 and A.C. voltage less than 0·1 R.M.S. were used. C_3 was variable between 100pF, and 10,000pF. Other conditions were

$P = 0$ ohms	$S = n \times 1,000$ ohms
$Q = 1,000$ ohms	$n = 1, 2, 3$, etc.
R is variable	$\omega = 2\pi \times 1,000$.

The results were plotted as g_m against V_g and integration gave values of i_a indicated by crosses in Fig. 5. The values of g_m were compared with μ/r_a from the first experiment. Although the latter results were more erratic they gave smoothed curves almost identical with the former. Fig. 3 gives the curves of g_a against V_a. For a pentode in which the equivalent circuit is a current generator with the anode impedance in parallel with the load, the reciprocal of r_a shows more clearly its effect. Fig. 4 is a graph of g_m against V_g for constant V_a. It is apparent that the curve of g_m is not very different for V_a between 40 volts and 200 volts. Fig. 5 is the $i_a V_a$ curve of the CV1136 for $V_{g2} = 200$ volts. The circles and crosses represent the values of i_a calculated from Figs. 3 and 4 respectively. Of the calculated values, 67 in all, 4 are outside ±3 per cent or 0.1 milliamps whichever is the greater and 4 on the $V_g = -3·0$ volts line are in doubt because of reading the small currents which are less than 1·0 milliamp and of guessing the shape of the curves of Fig. 4 below −3·0 volts.

Practical Details

In making the measurements as much care must be taken in setting the D.C. voltages and using reliable instruments as in any precautions taken with the bridge itself. It must also be remembered that above $V_g = -0·5$ volts the input resistance of the valve falls and the resistance

R must be small compared with it. The two bridges can be easily changed to each other; a double pole two way switch will make the necessary alterations. A step down transformer is recommended for the input to the bridge because a mains operated B.F.O. will produce a high proportion of 50c/s at the very small voltages required to operate the bridge. In this respect a tuned amplifier with

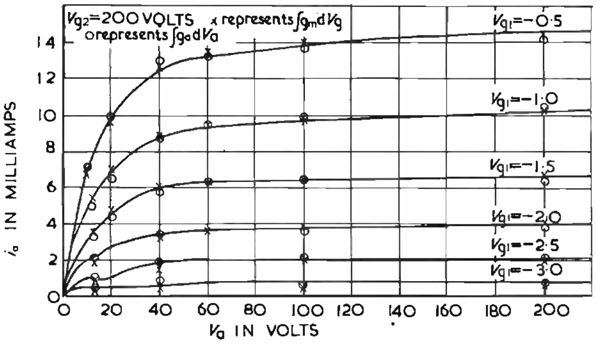


Fig. 5. Comparison of the anode characteristics with those computed from the output and mutual conductances

a gain of about 10,000 at 1,000c/s has been found sufficient to give a sensitive balance and at the same time to reduce unwanted noise.

Conclusion

The two bridges are capable of measuring the three parameters of a triode or pentode to within 3 per cent. This has been checked by the experiments on a CV1136 pentode by integrating the parameters and showing that they predict the static characteristics of the valve. Since D.C. passes through only one resistor and this can be fixed normally at 1,000 ohms, the voltage on the anode can be calculated and does not change as the bridge is balanced. This last is not true of the usual bridges where the D.C. passes through each resistor in the bridge. The small A.C. voltage applied to the grid is sufficiently close to the mathematical ideal for practical purposes. Several schemes for deriving grid bias from a power pack were considered but none was found so satisfactory as the battery bias. The type of power pack used and its impedance is without consequence except if the smoothing is not good then the parameters will be subject to a 50c/s variation and the balance will not be sharp. The bridge supplies more information than is required in the calculation of valve gain, but in non-linear theory, a field of study which is rapidly gaining importance, the author believes that is will supply the data, with sufficient accuracy for the formulation of the non-linear equations.

Acknowledgment

The writer wishes to acknowledge the advice and help given by Prof. J. Greig in the preparation of this paper.

Adhesive Tape Resistors

By M. Lorant

A MAJOR disadvantage of printed circuits has been the difficulty of incorporating satisfactory resistors. This difficulty has been largely overcome by an adhesive tape resistor method recently devised by the U.S. National Bureau of Standards.

In this technique, circuits are first printed in narrow metallic bands on insulating bases, leaving a small gap at each point where a resistor is required; one of the self-adhesive resistors is then cut from a strip and pressed into position. Much better control of resistance value is possible than with previous printed resistor methods, and higher yields of acceptable assemblies are assured. The tape resistor has been developed to operate satisfactorily at temperatures up to 200°C; in other electrical characteristics it is similar to present film-type carbon resistors.

The resistor consists of a mixture of graphite or carbon black, resin, and solvent applied, in a thin layer, to a thin roll of asbestos paper tape. The resistive coating is sufficiently adhesive to stick to an insulating base plate and to make satisfactory electrical contact with metallic terminals. When the resistor is in position, the resistance film is protected by its asbestos-tape backing. Resistor dimensions are kept constant; a variety of coating formulations give a range of values from about 100 ohms to 10 megohms (Fig. 1).

Silicone resin is used for the binder-adhesive because of its suitability for high-temperature operation. Since the curing temperature of the silicone resin formulations is high (300°C), and since curing is done after the resistors have been positioned in the circuit, the tape resistor is at present applicable only to glass or ceramic base materials.

The possibility of varying resistor dimensions to obtain a range of values was considered, but rejected and resistor dimensions were standardized at a length of 0·5in. (0·3in. interelectrode distance) and a width of 0·13in. ± 0·02in.

Both natural and synthetic graphites, as well as various carbon blacks, are used in the resistor formulations. Values of resistors are varied by changing the ratio of carbon to resin in the mixture and by using different carbons. The proportion of carbon to resin ranges from 10 to 50 per cent.

Tape resistors made from graphite mixtures have proved remarkably stable at ambient temperatures of 200°C.

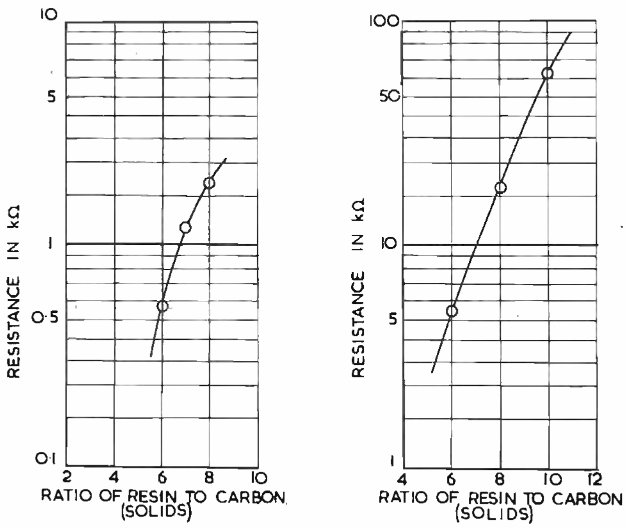


Fig. 1. Typical formulations

Unfortunately, however, the useful upper limit of the graphite formulations seems to be about 5,000 ohms. Carbon blacks, which are less desirable at high temperatures, give values from 5,000 ohms to 10 megohms. For most resistance ranges, however, carbon-black tapes have been made which are satisfactory at 170°C.

The curing process hardens the resistor, bonds it more firmly to the plate, and stabilizes its electrical characteristics. Although the optimum cure for different formulations differs considerably, a compromise cure of 4 hours at 300°C has proved satisfactory and has been adopted as standard.

Recording Low Frequency Phenomena on Magnetic Tape

By L. Molyneux,* B.Sc.

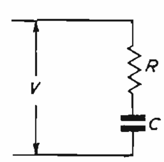
IN the field of medicine, it is often necessary to record information for long periods in order to observe a possible abnormality. If the abnormality does not occur, the information may be useless, so that pen or film recording becomes expensive and wasteful. It would be very useful therefore, to be able to record on some medium from which abortive runs could be erased, the interesting pieces of information being stored either on the medium or transferred to one of the normal recording systems. Magnetic tape provides just such a system with the added advantages that the time scale of the stored information can be changed with ease, and if ink-writers are being used as a final presentation, they may have their effective frequency response increased. (Appendix 1.)

The difficulty of using magnetic tape is the poor response at low frequency of the conventional system. This difficulty may be approached in a fundamental manner as in the current RCA laboratory experiments,[1] or it may be overcome by some modulation system. Of the possible systems, frequency modulation has been chosen as the most suitable, and it is proposed to describe a simple yet accurate method.

Theory of Operation

Fig. 1 is arranged so that whenever the voltage across

Fig. 1. The basic principle



the capacitor reaches a certain value, V_{ref}, the capacitor is discharged. Let the capacitor voltage at any time, t, be v volts and let $v = 0$ when $t = 0$, then if the voltage applied to the network is V volts

$$v = V\,(1 - \epsilon^{-t/CR})$$

$$v = V\left\{1 - \left(1 - t/CR + \frac{(t/CR)^2}{2!} \dots\right)\right\}$$

$$v = V\left\{t/CR - \frac{(t/CR)^2}{2!} \dots\right\}$$

If $t/CR \ll 1$ then terms of second and higher orders may be neglected, so that $v = Vt/CR$

The circuit is arranged so that whenever v reaches V_{ref}, the capacitor is discharged putting $t = 1/f$

$$V_{ref} = V/fCR \text{ therefore } f = V/V_{ref}\,CR$$

That is to say, the number of times the capacitor discharges per second is directly proportional to V. Perhaps the simplest way of ensuring that the above inequality holds good while at the same time obtaining workable voltages, is to use the Miller integrator, defining V_{ref} in the anode circuit.

The Transitron Miller with the addition of one diode provides a convenient way of performing the necessary functions though more accurate ways could be devised. (Appendix 2.)

* *University of Durham*

Practical Circuits

The input cathode-follower (Fig. 2) performs two functions.

(1) It provides a Bias Voltage so that V is always very much greater than the grid swing.

(2) It ensures that the 100kΩ integrating resistor is fed from a constant impedance.

As the circuit stands, the output is suitable for driving a high impedance recording head. (Appendix 3.) The negative rail may be dispensed with, if lower accuracy of modulation is allowable. In this case, the cathode follower is returned to H.T.− through a 3·9kΩ resistor.

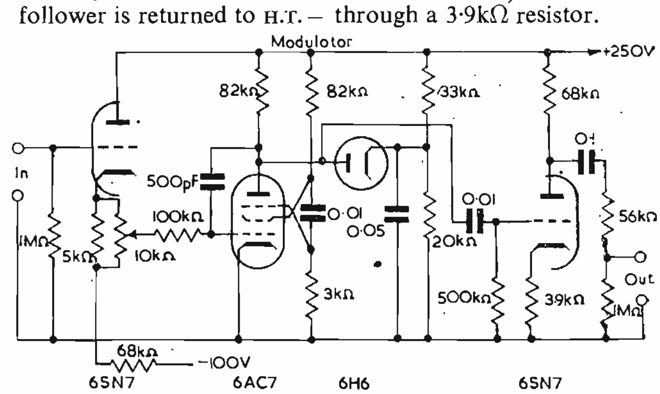
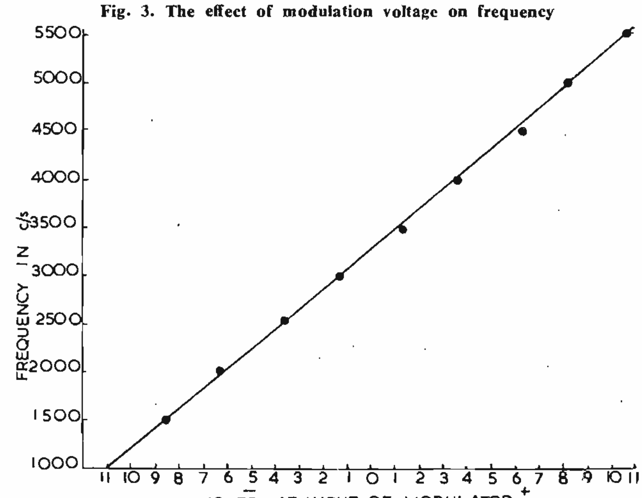


Fig. 2. The audio-frequency modulator

Fig. 3. The effect of modulation voltage on frequency



Performance

Fig. 3 shows the plot of frequency/input voltage. It will be seen to be sensibly linear over an input voltage change of ± 9 volts.

Demodulation

The standard circuit used for direct reading frequency meters if used with a low-pass filter is an adequate demodulator. No originality for this circuit can be claimed,[2] and it is given for the sake of completeness. (See Fig. 4.) Again, the negative rail may be dispensed with, this time at the inconvenience of having some 10 volts of D.C. superimposed on the output.

Overall Performance

Fig. 5 shows the frequency response of the complete system. It will be seen that it is sensibly flat from D.C. to 50c/s and only 3db down at 100c/s. This could be improved with a well-designed low-pass filter.

Fig. 6 shows a static plot of input against output. From this it will be seen that the system has a voltage gain of approximately 1/5.

As a practical demonstration of the system, an electrocardiogram was recorded simultaneously on paper and tape, then the tape reproduced back into the paper, and the two traces printed one above the other, the upper being the original. (Fig. 7.)

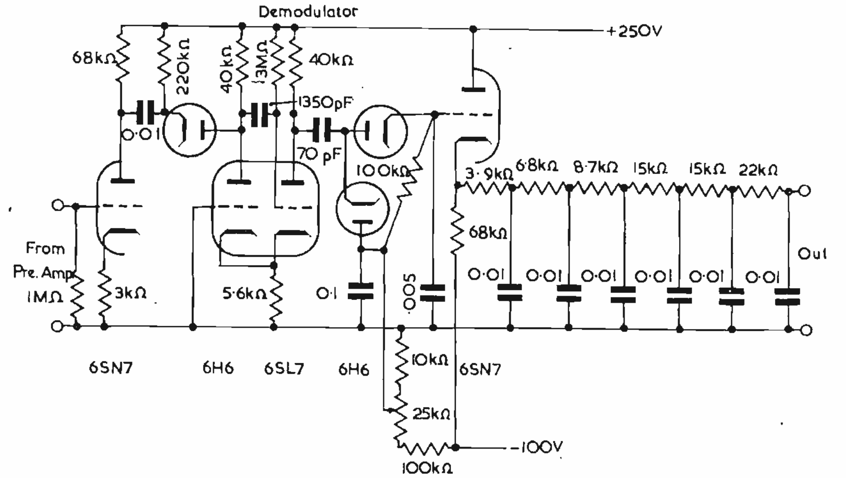


Fig. 4. The demodulator

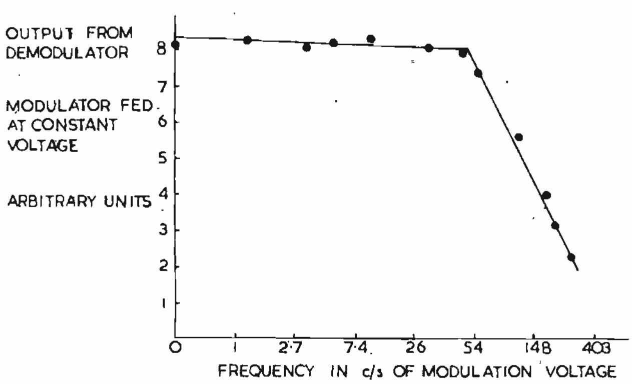
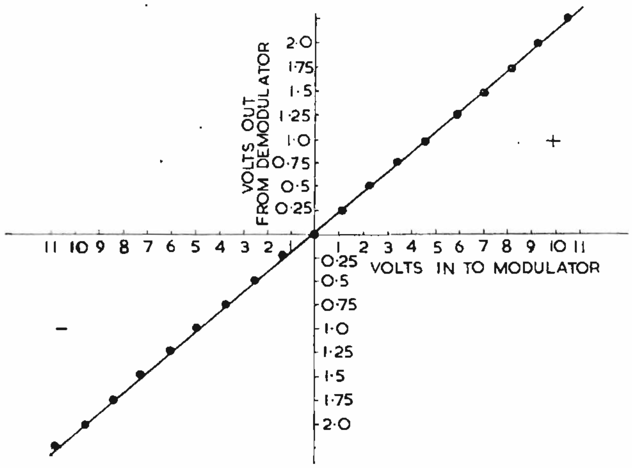


Fig. 5. Overall frequency response of the equipment

Fig. 6. Overall amplitude response (D.C. conditions)



Acknowledgments

The author would like to thank Professor E. A. Pask for his encouragement and permission to publish the work, and also Mr. C. J. Duncan of the Department of Photography and his staff for their help in the preparation of the diagrams.

Appendices

1. Increasing the effective frequency response of direct writing pen recorders. If the modulation frequency is made high, say, 20,000c/s, then the frequency response of the system can be increased to about 1,000c/s. The tape is played back at 1/10th of recording speed, so that the pen only has to deal with frequencies up to 100c/s, though the record will represent a frequency response of 1,000c/s.

2. The use of a multia[3] as a voltage comparator at the lower end of the anode wave form instead of relying on the anode "Bottoming".

3. In the author's experiments a Wright & Weaire tape deck was used.

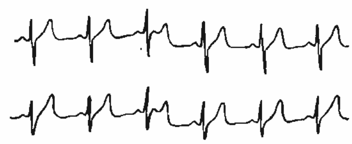


Fig. 7. Comparison between input and output

Upper trace input signal (electrocardiogram) recorded by conventional ink-writer direct. Lower trace—same signal, reproduced by same ink-writer after "storage" on magnetic tape.

References

[1] Magneto Optical Transducers, *RCA Review* XI (1950).
[2] Counting Rate Meters, National Nuclear Energy Series, *Electronics*, VI.
[3] Comparators Voltage. M.I.T. Laboratory Handbook, Vol. 19.

Addendum:

Since the preparation of this paper, information has come to hand of a "Frequency Conversion Unit" made by Messrs. Kelvin & Hughes, which gives practical realization to Appendix 1.

A Single Valve Delayed Pulse Generator

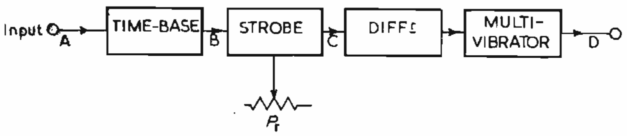
By P. A. V. Thomas,* B.Sc.

IN multi-channel equipment it is often necessary to generate a series of pulses for the purpose of gating of alternative signals into a common channel of the equipment. It was for this reason that the circuit given was developed in order to keep the number of valves to a minimum for obvious reasons.

Existing Methods

There exist several arrangements for generating delayed pulses depending on the conditions and accuracy required, e.g. for fixed short pulses and delays of high precision, delay lines are ideal, and for longer times there are several circuits available such as the Phantastron, Bootstrap, etc.[1,2] For medium precision a common arrangement is a multivibrator driven from a strobe (see Appendix) as shown diagrammatically in Fig. 1, the method of operation being outlined below.

At time t_1 a time-base B of duration T_1 is begun and, at time t_2, reaches the value V_r selected by means of the potentiometer P_r; the output of the strobe is a pulse C of duration T_2 which is not constant. If, however, this pulse is differentiated by means of a short time-constant *RC* network and is used to trip a monostable multivibrator, a constant width pulse D of duration T_3 is generated; thus a pulse is generated whose phase (relative to a fixed reference time t_1) and duration are independently variable as required.



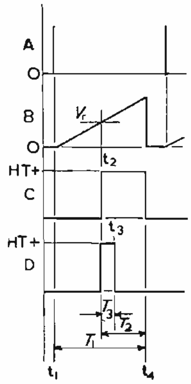


Fig. 1. Medium precision delayed pulse generator used as basis for single valve pulse generator, and (right) the associated waveforms

Unfortunately all these systems use several valves and a circuit was developed based on the scheme given in Fig. 1. In general a time-base will be available for displaying the signals on a cathode-ray tube, and the circuit shown in Fig. 2(a), together with the waveforms in Fig. 2(b), requires a positive time-base; with a slight modification it can be operated from a square wave input as detailed later.

Time-base Driven Square Wave Generator

With reference to Fig. 2, and assuming C' and R' not to be connected, the sequence of events is as follows:

At time t_1, V_1 is cut-off due to the negative bias v_1 while V_2 is in a state of full conduction due to the positive bias v_2; thus V_{a1} is at H.T.+ while V_{a2} is at a low voltage, dependent on the valve characteristics and the anode load.

At time t_2, V_{g1} reaches V_{co1}, the cut-off voltage of V_1, and the valve begins to conduct causing it's anode voltage to drive negative, this being transferred to the grid of V_2 by the coupling capacitor *C*; thus V_2 is driven beyond cut-off and V_1 becomes fully conducting with the respective anodes being at H.T.+ and a low voltage. V_{g2} now rises on an exponential determined by the values of *C*, R_2 and v_2, until time t_3, when this voltage reaches V_{co2}, the cut-off voltage of V_2; this causes V_2 to conduct causing V_{a2} to fall while V_{a1} remains low.

The two valves remain in this state of full conduction until time t_4, the end of the time-base, when the conditions return to those at time t_1 and the whole sequence of events is repeated. Thus the output obtained at 2 is a square pulse whose three dimensions* may be varied independently by means of the three controls provided, viz.:

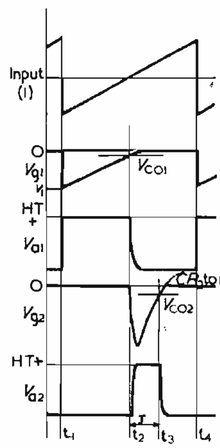
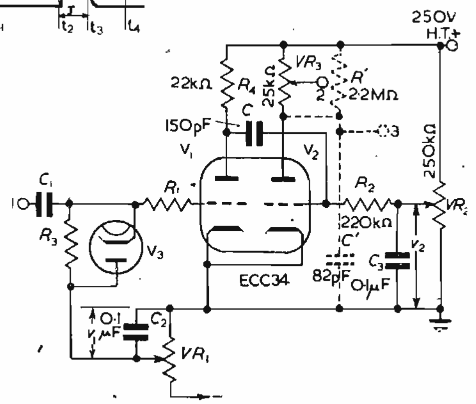


Fig. 2. Time-base driven delayed pulse generator, and (left) the associated waveforms

VR_1—to vary the delay by altering the time at which V_{g1} reaches V_{co1}.

VR_2—to vary the width of the pulse generated by altering the voltage to which the exponential rises and hence the time t_3 when V_{g2} reaches V_{co2}; alternatively *C* and/or R_2 could be made variable, hence varying the time-constant of the discharge circuit.



VR_3—to vary the amplitude of the pulse generated.

V_3 is provided to ensure that the time-base always starts from the same potential and R_1 is included to limit the value of grid current flowing when V_1 is conducting.

Using Square Wave Drive

As mentioned above, in the absence of a time-base a square wave drive may be used, the modification being shown in Fig. 3, the circuit becoming virtually two timing networks $R_3'C_1'$ and R_2C. When the square wave is applied, the front drives V_1 beyond cut-off and would remain there but for the short time-constant of $R_3'C_1'$ which causes V_{g1} to rise towards v_1 but at time t_2 reaches the cut-off voltage of V_1 and allows it to reconduct. The anode voltage is a square pulse as shown, being identical to V_{a1} of Fig. 2(b) and thus the remainder of the operation is the same.

* *Royal Technical College, Glasgow*

* *By dimensions are meant the "time delay," "time width" and "voltage height."*

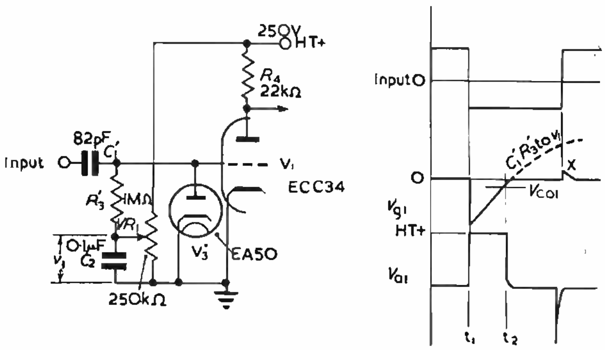


Fig. 3. Modification to Fig. 2 for square wave drive

The diode V_3' is not essential but is incorporated in order to reduce the magnitude of the "pip" X of the V_{g1} waveform which causes a subsidiary short pulse to be generated at V_{a2}; in some cases this may not be important, in which case V_3' may be omitted.

Delayed Time-base Output

If a small amplitude time-base output is required, instead of a square pulse, a capacitor C' and resistance R' (instead of VR_3) may be connected as shown dotted in Fig. 2(a), thus making $C'R'$ into an exponential charging circuit giving an approximately linear time-base at 3, assuming $C'R' \gg \tau$. If a larger output is required a linearizing circuit could be easily incorporated.

Conclusion

Both methods of driving have been tried successfully and oscillograms are shown in Fig. 4 when using a square wave drive and the Fig. 3 modification. The time-base drive gives slightly better results due to the constant slope of the V_{g1} waveform, at the point of reaching cut-off from the negative extremity, when varying the phase (or delay); this defect, when using a square wave drive, is noticeable in Fig. 4(f) but in general is not important.

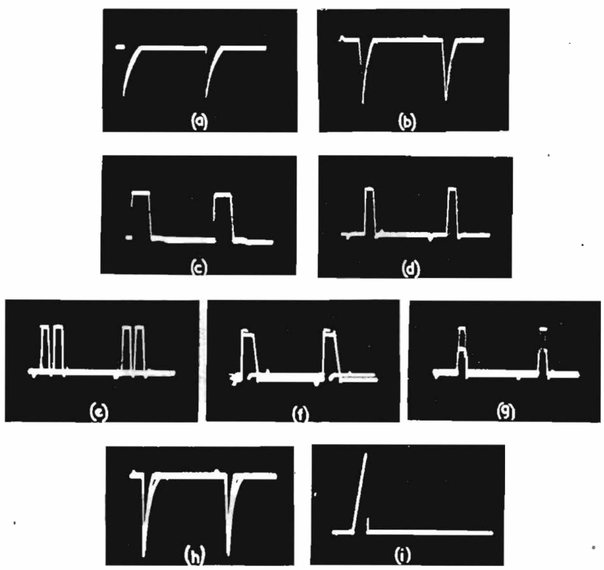
Appendix

The Strobe Circuit

The strobe circuit referred to in the text and shown in Fig. 5 is based on the Schmitt circuit.[3]

Fig. 4. Waveforms obtained using 5kc/s square wave drive

(a) *Grid of* V_1. (b) *Grid of* V_2. (c) *Anode of* V_1. (d) *Anode of* V_2; (e), (f) (g) *Anode of* V_2, *showing variation of* VR_1, VR_2, VR_3 *respectively*; (h) *Grid of* V_2, *showing variation of* VR_2; (i) *Anode of* V_2, *with* C' *and* R'.



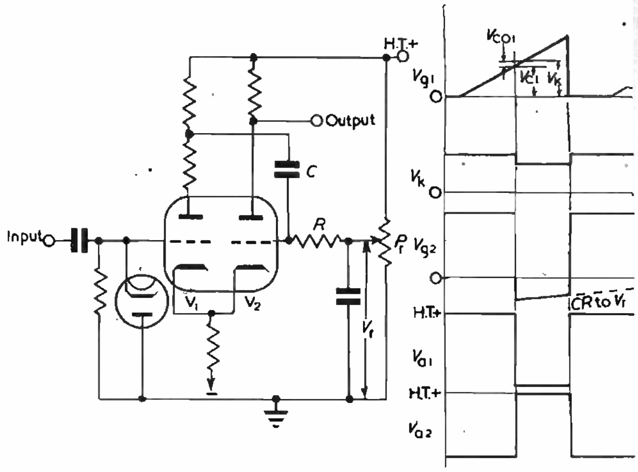


Fig. 5. The strobe circuit

Initially V_2 is conducting due to the positive bias V_r provided by potentiometer P_r and, by it's cathode-follower action, causes V_1 to be cut-off.

If a positive time-base is applied to the input so that V_{g1} can exceed V_k, V_1 begins to conduct when V_{g1} reaches V_{c1}; this causes V_{a1} to fall driving V_{g2} negative through the coupling capacitor C, thereby cutting-off V_2. Due to the long time-constant of CR these conditions remain until the end of the time-base when the process is reversed by V_{g1} going negative cutting-off V_1 and driving V_2 into conduction. Thus positive and negative square pulses are generated at the anodes of V_2 and V_1 respectively.

Acknowledgment

The author expresses thanks to The Royal Technical College, Glasgow, for permission to publish this paper.

REFERENCES

1 Williams, F. C., and Moody, N. F.: Ranging Circuits, Linear Time-base Generators and Associated Circuits, *J.I.E.E.*, *93*, Pt. IIIA, 1188 (1946).
2 Electronic Time Measurements, *Rad. Lab. Series*, 20, Massachusetts Institute of Technology.
3 Schmitt, O. H.: A Thermionic Trigger, *J.S.I.*, *15*, 24 (1938).

Letters to the Editor

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

Are We Becoming Slaves to Standardization ?

DEAR SIR,—The space you are allowing for the discussion of standardization of terms, symbols, and abbreviations is, I am sure, fully justified, for uniform and logical practice is a valuable guard against error and misunderstanding, and betokens an orderly mind.

Already considerable progress has been made, and you are to be congratulated on giving a lead in the drawing of circuit diagrams. The term "resistor" has become almost universal, although I remember when it, like "picofarad", was considered a laughable affectation. So it is surely defeatism to argue that a silly and illogical term cannot be changed because it is too firmly rooted.

J. Scott-Taggart (p. 64 in the February issue) considers the I.E.E. is puritanical in objecting to "A.C. current", but how they can be said to "impose long clumsy spelt-out alternatives" by preferring "A.C." is not clear. When people talk to me about "A.C. current" I ask them to say the whole thing out in full, and it sounds so foolish that it is a cure for the habit, if anything is ! I readily join Mr. O. S. Puckle (p. 87, February issue) and the I.E.E. in the puritan camp.

"K" instead of "k" for "kilo", as advocated by Mr. Puckle, is certainly more logical, but I am sure nobody is misled by the small letter into supposing that it denotes a sub-multiple, and weight must be given to the fact that it is an established part of the metric system and universally used in continental countries.

The only other point where I differ from Mr. Puckle is in his rule that units named after a person should have a capital letter whether written in full or abbreviated. I support Prof. G. W. O. Howe in holding that although the name of a unit may honour a person by its derivation from his name, it is nevertheless a new word in the dictionary—a common noun and not a proper noun—and this should be clearly recognized by applying the normal rules of English for the use of common nouns. "Ampère" is the name of a man, and "ampere" is the name of a unit; and it is wrong to use the capital letter, as Mr. Puckle advocates, except where the rules of English require it; and it is also wrong to retain the accent. Would Mr. Puckle say, for example, "A resistance of several Ohms" (unless, of course, he were reporting the obstruction he experienced from members of that family) ? I go farther and venture to say that even the B.S.I. is wrong in departing from the rule for the plural of common nouns ending in "y" by prescribing the outlandish "henrys". These names must either be common nouns or proper nouns, not an illogical and hitherto unknown hybrid; and the B.S.I. ought not to tamper with established English usage in order to create such a hybrid.

Another wanton departure from English is the form reported by Mr. Scott-Taggart as the standard for plurals of abbreviations, e.g., "e.m.f.'s." The apostrophe in English denotes either the possessive or letter(s) omitted; never the plural. Nor is there the slightest need for such a breach; "E.M.FS" is perfectly clear.

But I am at one with Mr. Scott-Taggart in favouring the term "circuitry". It is high time for the meaning of "circuit" to be more precisely defined, for it has spread far from its original significance in electrical contexts, and some of its remoter duties might well be transferred to "circuitry".

The "straight-across" non-connecting crossing in circuit diagrams may be satisfactory if one can be quite sure everybody sticks strictly to the rule of staggered junctions. But when inking-in a diagram it is quite common for a dot to form at a crossing, and can one be absolutely sure that every reader will understand that no junction is intended ?

Yours faithfully,

M. G. SCROGGIE,
Bromley, Kent.

An Electronic Ultramicrometer

DEAR SIR,—I read with considerable interest the article by W. Alexander in the December 1951 issue of ELECTRONIC ENGINEERING describing a use for an otherwise unwanted effect in octode frequency changers. Shortly after reading Lukacs' article in *Wireless World*, I built up a unit to check the effect and subsequently used it for many purposes.

One particular use which may be of interest to your readers is shown in the circuit diagram below (Fig. 1). A particularly valuable feature is that the capacitor microphone may be some 20ft or so away from the main unit, the necessary connexion being made by a low loss coaxial cable. The maximum sensitivity recorded was of the order of 200 volts per pF at an oscillator frequency of 10Mc/s when using a high Q coil and tuning capacitance of the order of 100pF in the control grid circuit. When coupled to a capacitor microphone, as shown in the circuit, the sensitivity was reduced through cable losses, etc., to approximately 10 volts per pF. With a capacitor microphone having a 1¼in. diameter back plate this is still enough to give sufficient output to feed a normal radiogram amplifier. The original unit is still in existence and continues to perform as well as ever.

The setting up procedure is to disconnect the capacitor microphone circuit and swing the tuning capacitor through resonance noting the highest and lowest values of the anode voltage or current. Then earth the control grid with a clip lead and adjust the cathode bias resistance control until the anode voltage or current is the mean of the two previous readings. Next disconnect the clip lead and it will be found that the curve is now symmetrical. The tuning capacitor is then set to bring the anode voltage or current to the same mean reading in the most sensitive part of the curve. The microphone cable and circuit is then reconnected and the microphone trimming capacitor adjusted to bring the voltage or current back to the middle point on the sensitive part of the curve.

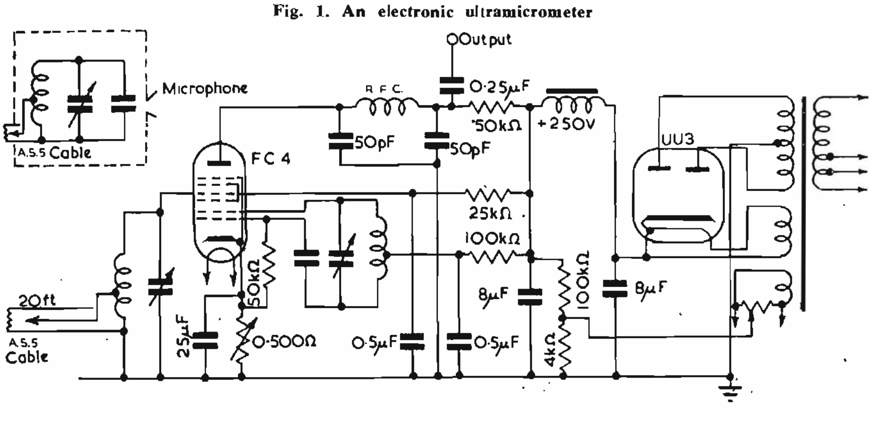
NOTE. It is quite easy with tuning capacitors of low minimum capacitance to tune the circuit to the second harmonic of the oscillator. The amplitude and sensitivity of the second harmonic response, will depend upon the valve and conditions of use.

The Mullard FC4 valve was found to be the most suitable for this purpose, but most heptodes with the oscillator grid nearer the cathode will work satisfactorily. The 6K8 triode hexode is also quite suitable.

Yours faithfully,

S. W. HOBDAY,
Senior Development Engineer,
Southern Instruments, Ltd.

Fig. 1. An electronic ultramicrometer



The author replies:

DEAR SIR,—I should like to add the following comments to Mr. S. W. Hobday's letter.

Enquiries have been made as to the earliest records of the use of both the Widdington and the Octode form of ultramicrometer circuit, and the following information should be of interest.

The possibilities of the latter form of circuit was first brought to the author's notice by Mr. Hobday, at that time with the B.E.A.I.R.A., early in 1938.

The Widdington circuit is fairly well known, and was originally described in *The Philosophical Magazine* in 1920, Volume 40, page 634.

The multi-grid valve circuit, when used as a capacitor microphone amplifier, has been patented by a Hungarian firm under Patent Specification No. 487913 (1936/37/38). Its use as a frequency modulation discriminator, and many other applications, are covered by a patent, in the name of J. A. Sargrove, Patent Specification No. 558036 (1942).

Yours faithfully,

W. ALEXANDER,

Electrical Engineering Dept.,
The University of Nottingham.

Electrical Computing

DEAR SIR,—I was very interested to read Mr. Priestman's comments in his letter in the January 1952 issue on the use of the substitution $(x + y)^2 - (x - y)^2 = 4xy$ in price calculating petrol pumps.

The same principle has been used with considerable success in a new electronic analogue computor now under development at the Imperial College of Science and Technology. The computor is required to calculate the auto and cross correlation functions of signals whose frequency spectra lie within the range 9 to 9,000c/s. In the process it has to determine the product of the two functions to an accuracy of ± 2 per cent.

The method employed is to form the following combinations of the given signals $x(t)$ and $y(t - \tau)$:—

$$e_1 = +x(t) + y(t - \tau)$$
$$e_2 = -x(t) - y(t - \tau)$$
$$e_3 = +x(t) - y(t - \tau)$$
$$e_4 = -x(t) + y(t - \tau)$$

These voltages are applied to the grids of four pentodes having the characteristics:—

$$E = R \cdot i_p = R(a_0 + a_1 e_g - a_2 e_g^2 - a_3 e_g^3)$$

The pentodes produce four outputs E_1, E_2, E_3 and E_4. These are combined in the following manner so as to yield the desired product and eliminate all unwanted terms:—

$$(E_1 + E_2) - (E_3 + E_4) = 4Ra_2 x(t) y(t - \tau)$$

The basic substitution is identical to that mentioned by Mr. Priestman. The method is a little more extended, however, as no devices are available which will produce the square of $(x + y)$ and $(x - y)$ directly, without also producing first and third order terms.

The complete multiplier employs four pentodes, three double triodes, and a handful of resistors and capacitors. In a simple computor required to form only one product (and thereafter one integral) this represents a considerable economy over any other analogue or digital system known to the writer. As it is hoped to publish complete details of the computor in the not too far distant future my remarks must be confined to a passing reference only.

Yours faithfully,

J. M. C. DUKES,

London, N.14.

The Effect of Valve Impedance on Phase Shift Oscillators

DEAR SIR,—The effect of valve impedance on the frequency and attenuation in phase shift oscillators using uniform phase shift networks has been fairly adequately dealt with recently. In some circumstances, however, it may be preferable to employ a graded network, because of its lower attenuation, in which each section of the phase shift network is made, say, 10 times the impedance of the previous section. When this is the case the shunting effect of each section on the previous one is negligible and each section provides the same phase shift, unlike the case of the uniform network where the phase shift in each section is different. Owing to this condition it is convenient to investigate the problem by a vector diagram, and a simple way of compensating for the valve impedance is shown.

If the equivalent generator impedance of the valve and its anode load is represented by R_g in Fig. 1, this appears in series with the first section of the network. Let the ratio of R_g/R be equal to K, where R is the resistance in the first section of the network.

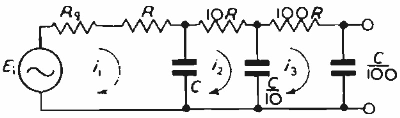


Fig. 1

The vector diagram for the three section networks is shown in Figs. 2 and 3. When K is zero, the three triangles ABO, BCO and CDO are similar as the ratio of reactance to resistance is the same in each section, the angles AOB, BOC, and COD are 60° and the frequency is given by the equation below.

3 *section RC network.*

$$|R/X| = \omega CR = \sqrt{3}$$

$$\text{and } f = \frac{\sqrt{3}}{2\Pi CR}$$

3 *section CR network.*

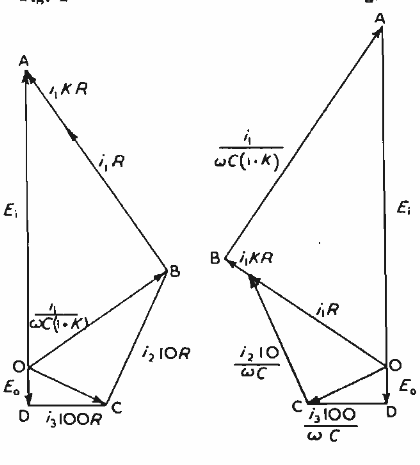
$$|X/R| = \frac{1}{\omega CR} = \sqrt{3}$$

$$\text{and } f = \frac{1}{\sqrt{3}.\ 2\Pi CR}$$

The attenuation coefficient V/V_g in both cases is $2^3 = 8$, and the amplification factor of the valve μ must be $\frac{R_A + R_L}{R_L} . 8$.

Vector diagrams for three-section networks

Fig. 2 Fig. 3



The effect of valve impedance is to alter the ratio AB : BO, but $\angle$ABO, $\angle$BCO, and $\angle$CDO remain right angles, and triangles BOC and COD are still similar. It is somewhat difficult to calculate this condition, but if instead the impedance of the capacitor in the first section is increased by a factor $(1 + K)$, all three triangles are made similar again and the same formulæ for the frequency coefficient apply as before. The attenuation is increased in the CR case to $8(1 + K)$, but is still 8 in the RC case.

Generally only 3 section graded networks are used, as the ratio of the input and output impedances of the network are awkwardly large with a higher number of sections, but the same treatment can, of course, be used for these.

Yours faithfully,

R. TOWNSEND,

The British Tabulating Machine Co., Ltd.

REFERENCES

[1] ROORDA, J. : Letter, *E. Engg. XXI*, 270 (1949).
[2] HINTON, W. R. : The Design of R.C. Oscillator Phase Shifting Networks, *E. Engg., XXII*, 13 (1950).
[3] TOWNSEND, R. : Letter, *E. Engg., XXII*, 116 (1950).
[4] TISSINGTON, R. S. : Letter, *E. Engg., XXIII*, 491 (1951).
[5] VAUGHAN, W. C. : Phase Shift Oscillators, *Wireless Engineer, XXVI*, 391 (1949).

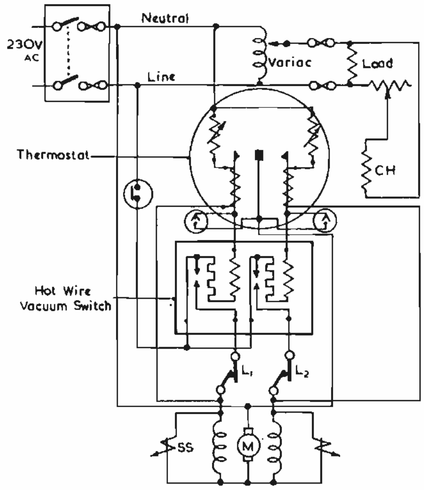


Fig. 1. The electro-mechanical voltage stabilizer

Electro-Mechanical Voltage Stabilizer

DEAR SIR,—Referring to the interesting article in the January 1952 issue of ELECTRONIC ENGINEERING on "A Simple Electro-Mechanical Voltage Stabilizer" by J. V. P. Long, describing a D.S.I.R.-developed voltage stabilizer using a 200CMH Variac (580VA) driven by a 24 volt reversible motor, in 1945 I designed a somewhat similar unit in association with Messrs. Sunvic Controls Ltd.

This apparatus, the wiring diagram for which is illustrated above, used a 100L Variac (2kVA) driven by a Drayton type "RQ" reversing geared motor, itself geared 10:1 reduction on to the Variac spindle. The unit supplied stabilized output voltage for laboratory pilot plant heating and operated successfully for about six months before being dismantled on the completion of the work in hand.

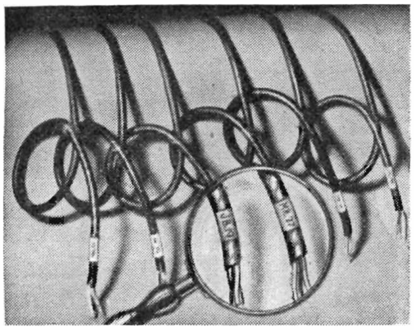
Yours faithfully,

JAMES MCCASH, B.Sc. (Eng.), A.M.I.Mech.E., A.M.I.E.E.

The Anglo-Iranian Oil Co., Ltd.

ELECTRONIC EQUIPMENT

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



Self-Adhesive Tapes

(Illustrated above)

INDUSTRIAL TAPES, LTD., have produced a range of printed Speedfix self-adhesive tapes to meet the demand for labelling for identification purposes, instructional notices, specification data, etc., on components and cables. A large range of identification codes and numerals are available to provide a means of branding cables before they are passed through a main conduit. Speedfix tapes can be overprinted to any specification, and are applied without paste or water to any smooth surface.

Bondex tape has been specially produced for labelling as it provides a complete protection to the written text, because it is placed between two layers of cellulose tape. The use of a transparent covering such as ethyl cellulose makes the label waterproof and impervious to oils, solvents or cold storage conditions.

Where tapes possessing a high measure of electrical resistance are required, either acetate or ethyl tape will be found applicable, for acetate tape has a dielectric strength of 5,000 volts and an insulation resistance of 15,000 megohms, and ethyl tape has a dielectric strength of 5,000 volts and an insulation resistance of 30,000 megohms. Both these tapes are waterproof, and Speedfix cellulose tapes are coated with a neutral adhesive which will render them harmless to copper wire.

Paper masking tapes are also available for holding applications, particularly in the construction of coils. and so are cloth tapes having similar applications, but these are recommended where extra tensile strength and thickness of material are required.

Industrial Tapes, Ltd.,
22 Dukes Road,
London, W.C.1.

Industrial Time Meter

(Illustrated bottom centre)

MESSRS. ALLIED ELECTRONICS, LTD., have developed an industrial time meter which will measure time intervals from half a second to several minutes with an accuracy of 1/100 second.

A stop watch is built into the instrument, and the operating circuit is so designed that the differential error due to the delay characteristic of the start-stop. mechanism is within the tolerance allowed by the N.P.L. on the accuracy of the watch.

The stop watch has a 7-jewel precision movement, and the large hand revolves in three seconds, calibrated at 1/100 second intervals. The small hand rotates in three minutes. The instrument has two terminals for connexion of the control contacts, and a zero re-set button, as well as a mains on/off switch and a primary fuse. A neon pilot lamp indicator is also incorporated, and lamp and photocell switches can be provided.

The power supply is for 200-240 volts A.C. at 50-100c/s, or by self-contained dry batteries.

The instrument is housed in a heavy gauge steel case, measures 9in. by 6in. by 5in., and weighs 10lb.

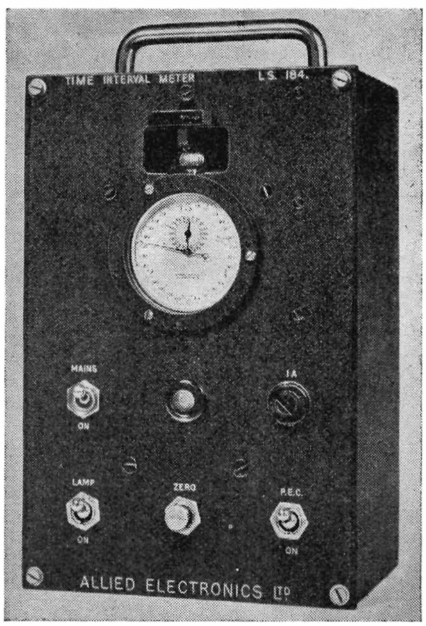
Allied Electronics, Ltd.,
28 Upper Richmond Road,
Putney, London, S.W.15.

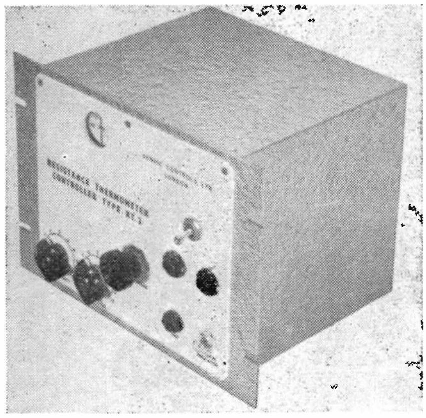
Resistance Thermometer Controller

(Illustrated top right)

THE new Sunvic resistance thermometer controller type No. RT.2 has been designed to overcome the effect of wide variations of mains voltage and frequency on the temperature control of electrically heated furnaces. It incorporates the Sunvic energy regulator principle in the output circuit of the controller to compensate for the change of control point which would otherwise accompany change of supply voltage.

The measuring circuit consists of an





A.C. resistance bridge containing the resistance thermometer and ballast resistance in two adjacent arms. The resistance ratio of the other two arms is adjustable by means of a precision potentiometer, and is used to set the controller to the required temperature.

Any out-of-balance signal from the bridge is amplified by a two-stage hard valve *RC*-coupled amplifier and gain is adjusted by means of a sensitivity control potentiometer connected across the grid of the input valve. The resistance of this potentiometer can be reduced to zero, permitting tests of the control unit under zero input signal conditions.

The output stage of the controller consists of a thermal cycling energy regulator unit operated by a double-triode. The cycling unit comprises two bimetal strips, one end of each being fixed. The free end of each strip carries a contact, and the strips are arranged to move in the same direction on increase of temperature. Each strip carries a heater winding which is in the anode circuit of one-half of the double-triode, whose anode supplies are in anti-phase. Under zero signal conditions, therefore, the two strips will be parallel to each other, but, when a signal is applied to the double-triode, the strips will move to or from each other depending upon the sense of the signal. This movement will vary the percentage "on" time of the thermal cycling unit, which is formed by the hot-wire vacuum switch in series with a supply transformer and a second heater winding on one of the two bimetallic strips, thus providing the proportional action of the controller. A portion of the same winding is connected directly to a secondary winding of the mains transformer and provides compensation for changes of mains voltage for that part of the load which is not controlled. Mains supplies to the amplifier stage are full-wave rectified A.C. It will be appreciated that any 100-cycle ripple will have no effect on the thermal cycling output.

Only two valves are used in the controller and these are both industrial vacuum types. No electrolytic capacitors are used.

The controller requires a supply of

200/250 volts or 100/130 volts at 40/100c/s. It has a range of 11.5 ohms to 48·0 ohms (30°C-1,100°C with 10 ohms platinum resistance thermometer) in six overlapping ranges selected by soldered links easily accessible at the back of the instrument.

Sunvic Controls, Ltd.,
10 Essex Street,
London, W.C.2.

Venner Process Timer Type P.T.B.

(Illustrated above)

DESIGNED for switching electrical apparatus either "on" or "off" after pre-set periods have expired, Venner process timers have numerous applications. They can also be fitted to a lamp, bell or buzzer circuit to give visible or audio warning of the end of a timing period, a feature which is particularly useful in industrial processes where machines switch off automatically, as they give warning of the completion of a process.

Both spring operated and synchronous motor driven models are available in various time ranges, and can be supplied for surface or panel mounting. On the spring-driven types, winding is accomplished automatically on setting the pointer to the pre-set time, so that the spring power is always set up.

The Type P.T.B., illustrated above, is a spring operated process timer. It has a rating of 5 amps up to 250 volts A.C. or 24 volts D.C. and a timing range of 0-60 minutes in 2 minute divisions. Its contacts are silver button, single pole changeover, and it weighs 8oz. Types P.T.A. and P.T.C. are similar, but have timing ratings of 0-8 minutes in 20 second divisions, and 0-90 seconds in 5 second divisions, respectively.

Venner Time Switches, Ltd.,
Kingston By-Pass,
New Malden, Surrey.

Low Voltage Focus Glass Cathode Ray Tube

THE RCA 17HP4 is a 17 inch, all glass rectangular picture tube utilizing low voltage electrostatic focus, which makes it possible to obtain the voltage for the focusing electrode from the low voltage D.C. supply of the receiver. The required focusing electrode voltage is only 0 to 2·5 per cent of the E.H.T. voltage.

The focusing electrode in the 17HP4 has its own base pin terminal so that designers can have a choice of focusing voltage for best results. This advantage is significant in view of the fact that the focusing voltage range within which a cathode ray tube gives optimum focus will change with different combinations of ultor and grid No. 2 voltages. Adjustment for this change is made possible by the separate focusing electrode terminal.

Using a design in which the cathode is not connected to any other electrode, the 17HP4 retains the advantage of low input capacitance when employed in a cathode drive circuit. Also, since the focusing electrode is not connected internally to grid No. 2 the 17HP4 has the advantage of permitting reduction in focusing voltage as grid No. 2 voltage is raised—a necessary relationship for optimum focus.

The cathode-ray tube has a filter glass faceplate, and an external conductive bulb coating. It features an ion trap gun requiring an external single field magnet, and has a design centre maximum E.H.T. voltage rating of 16,000 volts. The picture size is 14$\frac{3}{8}$in. by 11$\frac{1}{8}$in.

RCA Photophone, Ltd.,
36 Woodstock Grove,
London, W.12.

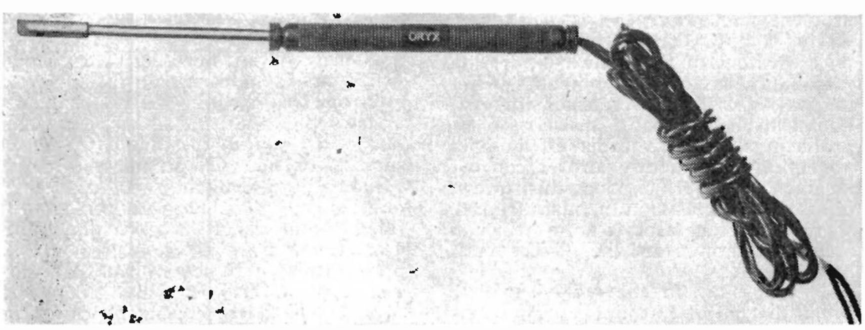
Miniature Soldering Iron

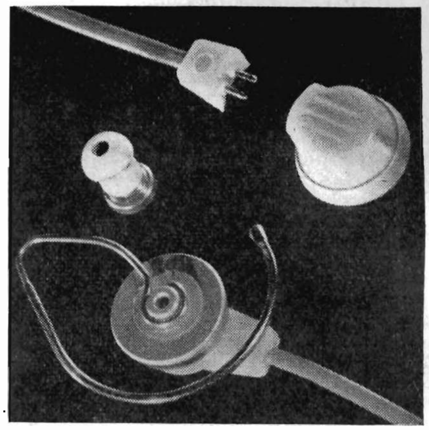
(Illustrated below)

RECENTLY introduced by the Oryx Electrical Laboratories is a new miniature soldering iron, Model 9, which is for general use. It contains no screws, washers, ceramic formers or mica which can flake, etc., and weighs approximately only a quarter of an ounce, or half an ounce including lead.

It is 6 inches long, and consumes less than 9 watts. It incorporates a 5/32in. diameter removable bit, and takes only 30 seconds to heat up. It can be supplied for 6, 12 or 24-27½ volts.

Oryx Electrical Laboratories,
BCM/ORYX,
London, W.C.1.





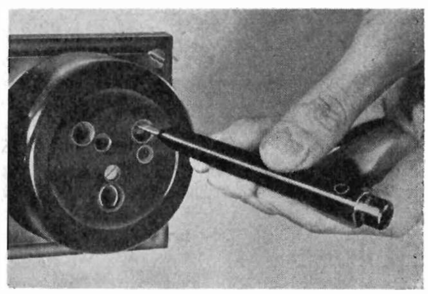
New Miniature Magnetic Earphone

(Illustrated above)

THE new Amplivox E5 earphone, which is only the diameter of a sixpence, is light and comfortable to wear, yet has high sensitivity and a smooth and extended frequency response. The construction is robust, and the unit will withstand considerable rough usage.

The P.V.C. insulated tinsel cord is strong and oval in section to ensure flexibility. The earphone is available in D.C. resistances of 2-2000 ohms, with a frequency range from 100 to 4000c/s. It weighs ½oz. The sensitivity, power handling capacity and frequency response can be adjusted, within limits, to meet individual requirements.

Amplivox, Ltd.,
2 Bentinck Street,
London, W.1.



Neon Voltage Indicators

(Illustrated above, Type No. Q.5000)

PHILIPS ELECTRICAL, LTD., have re-introduced two neon voltage indicators for use in testing low and medium mains installations.

The pencil type, No. Q.5000, can be used on A.C. or D.C. mains voltages between 110 and 500V. It is housed in a black insulating pencil-shaped case.

The voltage and polarity indicator, No. Q.5005, is a much larger type suitable for 80-750V A.C. and 100-750V D.C., and for indicating polarity on D.C. It has two black "Philite" moulded insulated test prods, fitted with collars to prevent accidental hand contact with the metal probes, joined by a 39in. length of rubber covered cable. One prod houses a type 4017 indicator lamp, which can be replaced.

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

BOOK REVIEWS

Further Laboratory and Workshop Notes

Edited by Ruth Lang, Ph.D., A.Inst.P., for the Institute of Physics. 290 pp., 177 figs., VIII plates. Edward Arnold and Co. December, 1951. Price 28s.

THIS is the second selection of notes reprinted from *The Journal of Scientific Instruments* by the Institute of Physics. Original publication was in general during or subsequent to 1946, and the techniques described are therefore applicable to problems likely to arise in present day laboratories. In all, some 150 scientific and technical workers have set forth their solutions to practical difficulties which have arisen in their own work. Many of these, though originally encountered in one field, are of interest to workers in others.

Clearly a book of this nature can hardly be expected to have any kind of logical development or homogeneity, and consequently its assessment is difficult. It would be both impertinent and invidious to select certain items as being of more value or greater elegance than others, but to give some idea of the scope and flavour of this book it is necessary to select quite arbitrarily some of these notes for comment. It must be emphasized that this choice is a purely personal one on the part of the reviewer and does not attempt to set any kind of order of merit on the notes.

Dr. Lang has grouped the notes into seven sections: 1, Graphs and Drawings; 2, Optical Devices and Techniques; 3, Devices for Liquids and Gases; 4, Heat, Thermometry and Furnaces; 5, Laboratory and Workshop Tools, Process and Devices; 6, Vacuum and Pressure Techniques; and 7, Electrical Devices and Ancillary Equipment and Techniques.

Probably all of these sections contain something of interest to engineers working in the electronics industry.

In the first section, there is a most useful and simple "Linear Scale for the Direct Measurement of Slopes of Curves," while further on a note concerning "Resistance—watts Computer and Curve Plotter" has an immediate appeal to any engineer faced with the tedious computation of resistance and power from a series of pairs of values of current and voltage. A short note (No. 21) in the optical section on "General Illumination of Photographic Darkrooms" should be of interest to any worker using photographic aids. A "Constant Level Device for Liquid Air" utilizing a high negative temperature coefficient resistor as the temperature sensitive element is described by Box and Walker, while the "One-Point" or "Full Level Indicator" using an exact gas analogy of the Wheatstone's bridge is very appealing in its simplicity.

There is a useful note (No. 37) on "The Care of Liquid in Glass Thermometers" by J. G. Durham which summarizes a great deal of practical knowledge on this subject, and a similar treatment is followed in a comprehensive discussion on "The Construction of Laboratory Electric Furnaces and Available Material" by L. Walden. Besides discussing constructional details, there are five most useful tables: 1, Approximate temperature colours; 2, Heating element materials; 3, Furnace refractories; 4, Refractory cements, and 5, Furnace insulation materials. This "integrating" note is one of several, e.g. "The Design of Drills" (note 46), "Machining of Plastics" (note 49), "Instrument Suspensions" (note 60), "Control of Humidity by Saturated Salt Solutions" (note 73), "Glass-to-metal Seal Design" (note 74).

Dr. New (note 64) points out that the pattern-makers steel contraction rule can be used as the secondary scale of a vernier, and Garrod and Gross describe a "Universal Coupling for use in Vacuum Systems" which has probably wider utility than stated by the authors, and an ingenious "Pressure Divider" (L. Cohen note 94) enables one manometer to be used over a considerable range of pressures.

The final section, dealing with electrical matters ranging from the design of solder tags to the recording of changes in radio activity seems, paradoxically enough, of least interest to the electronic engineer. This is probably due to the fact that it is concerned with matters immediately within his own sphere and his approach to the problem is therefore similar to that of the authors', while the problems solved in the rest of the book, though of interest and use to the electronic engineer are solved by specialists in other fields.

The volume is well presented, illustrated and indexed, and it seems likely that any practising engineer would derive something of immediate value from studying it.

K. G. LOCKYER

The Measurement of Radio Isotopes

By Denis Taylor, M.Sc., Ph.D., M.I.E.E., F.Inst.P. 118 pp., 40 figs. Methuen and Co., Ltd., London. September, 1951. Price 6s. 6d.

THIS little book is one of a series of monographs on physical subjects which, as the publishers emphasize, is intended to supply research workers and others without specialist knowledge with a compact statement of the up-to-date position in each of the subjects covered. Dr. Taylor has obviously taken careful note of his terms of reference, and, as a result, has produced a book which will be extremely useful to non-specialist users of radio isotopes.

It will, of course, be appreciated that to an acknowledged master of his subject, as the author undoubtedly is, the chief problem with which he is faced when writing a book of this type is to decide on the extent of the knowledge he may reasonably assume his potential reader to possess. Moreover, since there are bound to be as many answers to this problem as there are readers of the book, no entirely satisfactory answer can ever be given. Such criticisms as this reviewer offers therefore arise in the main from the slightly different aspects from which he and the author regard the subject matter of this book.

Turning now to the text—it will be found that in his Introduction Dr. Taylor gives a fascinating glimpse of some of the present known applications of radio isotopes in research, medicine and industry, which will tempt the reader to explore further in this interesting field. One felt, however, that it would have been useful to have included some brief information as to the chief isotopes at present available, together with their most important applications. There follows an excellent chapter on "Fundamentals." Then, the author proceeds logically to Chapters III and IV on "Radioactivity Measuring Apparatus" and "Counting Systems," which contain much useful information, but in one of two places there would appear to be too detailed descriptions of specific equipments. Such information in a swiftly moving field like the one covered, tends to grow out of date very quickly and, moreover, is not really appropriate to a book of this scope. Chapters V and VI —"Statistics" and "Source Geometry and Self-Absorption"—are first class, and packed with information which the reader will find invaluable. Chapter VII on "The Method of Measurement and Correction Factors" is also good, and contains some valuable data, but here again there is an occasional tendency to become too detailed on particular points. In Chapter VIII, a number of additional counting systems are described in a very clear and concise manner. A minor point is that it seems that the correct position for this chapter would be at the end of Chapter IV on "Counting Systems." The final chapter on "Health Hazards and Radiation Monitors" is dealt with in a very practical manner, and the information it contains is, of course, essential to all those who wish to make use of radio isotopes—this new tool of which we shall undoubtedly see and hear more in the future.

Finally the reviewer would like to pay tribute to the author by pointing out to those not already aware of the fact that, in no more than a decade, he has established himself in the front rank of those who have been engaged in two entirely new scientific techniques—firstly radar, during the war years, and now nucleonics.

L. OURA

Electronics

By J. Millman and S. Seely. 598 pps. 2nd Edition. McGraw Hill Publishing Co. 1951. Price 66s.

IN these days, when there are so many new books appearing on the subject of electronics, it is quite an event to have a new edition of a familiar text which has been one of the standards on the subject for the past decade. The first edition, published in 1941, dealt in a most effective manner with some of the fundamental aspects of vacuum tubes. The authors took as their main task the presentation of basic physical principles, and applications were used mainly as illustrations of these principles. During the past ten years there has been rapid and spectacular change in the field of electronics, and the authors have been faced with the problem of deciding how much of the new material should be included in a fresh edition. Wisely, they have made no radical changes in the general layout and, although much of the book has been re-written they have maintained the same fundamental approach. The chapters dealing with basic physics, particularly those on the electron theory of metals and the kinetic theory of gases, are very well done. They have been recast to give qualitative treatment of broad principles prior to covering the more complicated quantitative theory.

Some of the new types of tube, such as klystrons, betatrons and cyclotrons, are dealt with briefly in the section on the applications of the motion of charged particles in electric and magnetic fields. Strangely enough, the magnetron, in spite of its importance and extensive development during recent years, has been dismissed in three pages, just half of the space devoted to it in the earlier edition. U.H.F. triodes and semi-conductors are also mentioned. The treatment of the newer parts of the subject is, on the whole, rather slight.

Those who are familiar with the first edition will share the authors' regret that the chapters on low frequency amplifiers have been omitted to keep the cost down. The omission has, to some extent, upset the balance of the book. Diodes, rectifiers and filters have almost twice the space given to triodes, multi-electrode valves and their applications.

It will be noted that the above criticisms are concerned solely with allocation of space to the different sections. The treatment of the subject matter is always beyond reproach, and this book will remain one of the few standard texts for those who are serious students of the phenomena occurring inside electronic tubes. It is strongly recommended to old and new readers, not so much for the new material as for the clear exposition of those fundamentals which will remain important, no matter what innovations or inventions may have to be covered when the next edition is due. The M.K.S. system of units is used throughout.

M. R. GAVIN

Television and F.M. Antenna Guide

By Edward M. Noll and Matthew Mandl. 311 pp., 223 figs. The Macmillan Co., New York, and Macmillan and Co. Ltd., London. October, 1951. Price 41s.

BOTH the authors of this book have had considerable experience in radio and television and have been teaching the subject for a long time. This may be the reason for the clear, logical and interesting manner with which they deal with television and F.M. aerials. On the loose cover it states that "you can find everything you want to know about V.H.F. and U.H.F. antennas and allied equipment for television and F.M. reception in this most complete, practical book," and this is really a very fair summary.

The book starts with an introduction to propagation which covers the basic facts of propagation of electromagnetic waves, polarization, field strength and directivity. It also contains some useful charts with which calculation of field strength at various distances at different frequencies may be made.

Then follows a description of various transmission lines, their characteristic impedance, use as matching devices, and the importance of matching for maximum power transfer. This chapter is followed by a discussion on the dipole, folded dipole, balancing methods using lengths of coaxial cable, and V and circular aerials. The impedance of these aerials is also discussed.

Chapter 4 covers more complicated aerials such as Collinear, End Fire, Stacked, Broadside Corner Reflector, Rhonbic and Yagi, and phasing and impedance matching are described. The usefulness of the various arrays over all the channels is also dealt with in some detail, which is obviously an important feature to be considered when choosing an aerial. The next 60 pages consist of very practical information on aerials generally, such as siting, choice of type, how to erect one, including what tools and fitting to use and choice of transmission line. The input system of several commercial television receivers is also shown and discussed. A neat valve voltmeter is shown which may be connected to the output of the vision receiver, the meter itself being on a cable of sufficient length to enable the "installation technician to take the instrument up on the roof." By this means he is able to observe the effects of aerial movement and can find the best position. This is probably a simpler method than use of Walkie Talkie sets which have been suggested and probably used!

The next 100 pages, roughly one-third of the book, describes and illustrates typical commercial television aerials. Polar diagrams are shown, and in many cases the frequency response is also given.

Finally, there is a short description of methods of reducing various forms of interference, such as multipath reflexions, unwanted signals and impulse noises.

This book should be of great value to anyone interested in, or working with V.H.F. aerials, and gave pleasure and information to the reviewer.

C. H. BANTHORPE.

Principles of Alternating Currents

By W. Sluckin. 320 pp., 165 figs. Cleaver-Hume Press Ltd. November, 1951. Price 10s. 6d.

THIS is Book Four of the Cleaver-Hume Electrical Series, intended primarily for educational purposes. As claimed on the jacket flap, the author's style makes easy reading in the main, but from the technical viewpoint, there are several places where the presentation does not satisfy the claim "singularly lucid." Very few, if any, of the "well-drawn diagrams" and photographs appear to be original, and many of them could have been replaced with different ones better suited to the purpose of the book.

The ideal book on principles should give its reader a clear appreciation of

BOOK REVIEWS (Continued)

fundamentals that he can apply to practice, and incidentally, to the answering of examination questions. The author of this book acknowledges "facilities" provided by various B.I.E.T. personnel; maybe this explains the presentation, which would appear to be aimed at answering some likely examination questions, rather than giving fundamentally a comprehensible treatise. A number of practical applications are introduced, often rather inadequately, giving the impression that the book was prepared around a list of things that must be included.

The early chapters, dealing with alternating currents, vector representation, alternating current circuits, electrical resonance and polyphase working, are quite well, but not outstandingly, presented.

The next two, on transformers, go into constructional details, including three phase types, before principles are properly introduced. Dealing with principles, the ideal transformer defined does not conform with the generally accepted conception, so the student is likely to become confused later. In one place the impression is given that a physical winding may have zero resistance. The giving of an empirical relationship between VA rating and volts per turn, right at the start, is considered ill-advised, there being enough fundamentals to tackle in the conception of a transformer without that.

Chapters on power transmission and distribution, and power factor improvement follow a more logical sequence, but the differentiation between impulse or velocity type turbines is vague—if necessary at all, it should be clarified; and the impression is given that a synchronous motor must always have a leading power factor.

The remaining chapters, on A.C. measurements, electronics, and some A.C. appliances, are very sketchy. The principles involved are often inadequately explained, and applications sometimes confused. In describing induction meters, the reader is simply told that "currents flow in such a way that the resulting forces drive the disk in a clockwise direction." The average housewife, without any technical knowledge at all, knows that current makes it go round! The reader of a book on principles wants to find out why certain actions take place.

The book frequently lacks concise definition of terms, and the author appears to use an unusual mode of expression for this purpose: when introducing a new term, he refers to it as "so-called," and the reader must infer its meaning from the context. For example, "According to the so-called Steinmetz coefficient this loss is proportional to $B_{max}^{1.6}$, but in practice it is safer to take B_{max}^{2}."

Quantitatively, this book is undoubtedly good value for money, and, as many students have little to spend on text-books with today's rising costs, it will appeal for its relatively low price.

N. H. CROWHURST

A.C./D.C. Test Meters

By W. H. Cazaly and Thomas Roddam. 180 pp. 112 figs. Sir Isaac Pitman & Sons Ltd. 1951. Price 18s.

THIS book deals with the principles, circuit design and practical construction of multi-range testmeters of workshop grade, a 0-1mA moving-coil movement being used, in most cases, as the basis of discussion.

Although this book is essentially practical in nature, sufficient facts and theoretical considerations and, where necessary, formulae are given to enable the efficient designing of any type of multi-range meter to cover the measurement of alternating or direct voltage or current, resistance and capacitance. It is, in fact, a collection of facts that, although normally well known, have been usefully combined together and well presented.

Foundations of Wireless

By M. G. Scroggie, B.Sc., M.I.E.E. Fifth edition. 328 pp., 236 figs. Iliffe and Sons Ltd. November, 1951. Price 12s. 6d.

THE fifth edition of this popular book on the basic principles of radio transmission and reception has been entirely rewritten and illustrated with new diagrams.

The early chapters of the book are devoted to the most elementary principles of radio theory, and it is assumed that the reader has no technical knowledge of the subject. Mathematics are avoided as much as possible, and under the heading "Into the Shorthand of Wireless" the use of algebraic symbols, graphs and circuit diagrams are explained for the beginner.

Apart from the fundamental laws of electricity and radio, and the associated equipment, there is an elementary introduction to the techniques of television and radar.

The book is written in Mr. Scroggie's usual clear and readable style, and is well produced.

F.B.I. Register of British Manufacturers 1951/52

24th Edition. 882 pp. Published for the Federation of British Industries by Kelly's Directories Ltd. and Iliffe and Sons Ltd. November, 1951. Price 42s.

THE F.B.I. Register for 1951/52 comprises seven sections as last year, including a classified buyer's guide listing over 6,000 F.B.I. member firms under alphabetical trade headings, an alphabetical directory of members with their full addresses, telegraphic addresses, telephone numbers, lists of products, home and overseas branches, agencies, etc., and a list of trade associations, brands and trade names with an indication of the products and their manufacturers.

The information is classified for quick-reference in English, French and Spanish, and all sections have reinforced guide tabs for reference purposes.

Publications Received

EKCO AIRBORNE SEARCH RADAR EQUIPMENT is a new handbook issued by E. K. Cole Ltd., of Ekco Works, Southend-on-Sea, Essex. This equipment is a 3cm radar system designed to: detect cumulo-nimbus clouds and hence areas of severe turbulence associated with such clouds; warn of high ground in the flight path of the aircraft, and navigate by map painting. The booklet covers the operational techniques and performance, and describes the units used.

THE "MACHINE TOOL" APPROACH TO SURFACE HARDENING and THE "MACHINE TOOL" APPROACH TO LOCALIZED HEAT TREATMENT are the first two brochures of a series describing all types of Birlec induction heating equipment. The approach used is to consider the heat-treatment unit as a machine tool with the same characteristics and advantages as the other units in the mass production line with which it is associated. Robust construction and simplicity of operation are thereby added to the inherent advantages of induction heating. Surface hardening applications mainly occur in those industries manufacturing automobile engines and other types of machinery parts, but localized heat treatment covers a wider field of application such as hardening, tempering or annealing components at various stages of their production. Copies of both these leaflets are available from Birlec Ltd., Tyburn Road, Birmingham 24.

NEGRETTI AND ZAMBRA 1850-1950. This delightful book has been produced as an historic account of the firm since its foundation in 1850. The book is printed on art paper, and attractively bound in cloth. The illustrations are of a high standard, and some of the reproductions from old prints of the company's early premises and the Crystal Palace are particularly interesting. Negretti and Zambra Ltd., 122 Regent Street, London, W.1.

1952 EDITION—CASES BY IMHOF'S is a new catalogue describing the stock range of standard cases available from this firm, and includes a short note on the production of metal cases of any size or type to special specifications. Imhof's design and development departments, where a case can be designed for individual requirements, are also mentioned. Alfred Imhof Ltd., 112-116 New Oxford Street, London, W.C.1.

TELEVISION DOWNLEAD CABLES is a leaflet published by British Insulated Callender's Cables Ltd., of Norfolk House, Norfolk Street, London, W.C.2, to describe their cable for television aerials. Coaxial, unscreened twin and screened twin are dealt with, their different constructions being briefly outlined, and alternative designs for each type are included.

ELECTRONIC MEASURING INSTRUMENTS FOR SCIENCE AND INDUSTRY is a 6-page illustrated brochure summarizing the wide range of electronic measuring equipment manufactured by the Instrument Division of Dawe Instruments Ltd., 130 Uxbridge Road, Hanwell, London, W.7, from whom a free copy is available on request.

LAB TESTED HIGH RESISTANCE PRODUCTS is an eight-page leaflet describing resistors, volume controls, fuse links, interference suppressors, potentiometers, etc., manufactured by the Radio Resistor Co. Ltd., of 50 Abbey Gardens, London, N.W.8.

Errata. We apologize for the misspelling of the name of the author of "Basic Electron Tubes", which was reviewed on page 90 of the February, 1952, issue. It should have been D. V. Geppert, not Gepput. Mr. R. D. Watts, the reviewer of "The Oxide-Coated Cathode", on page 43 of the January issue, asks us to apologize for a mistake he made in the third paragraph of his review. In the second sentence, "and the statement that the maximum saturation current increases . . . " should read "and the statement that the time to reach maximum saturation current increases . . . "

NOTES FROM THE INDUSTRY

The R.E.C.M.F. Exhibition. The ninth annual private exhibition of the Radio and Electronic Components Manufacturers' Federation will be held in the Great Hall, Grosvenor House, Park Lane, London, W.1, from Monday, April 7 to Wednesday, April 9.

ELECTRONIC ENGINEERING will be exhibiting on Stand 90, where readers will be welcome. Copies of the journal, monographs and reprints will be on sale.

Admission to the exhibition will be by invitation only. Further details may be obtained from the Secretary, the R.E.C.M.F., 22 Surrey Street, Strand, London, W.C.2.

Brit.I.R.E. Television Conference and Exhibition. The Scottish Section of the British Institution of Radio Engineers is holding a conference and exhibition in Glasgow on March 14 and 15 to mark the opening of the Kirk O'Shotts television transmitter.

A programme of papers on many aspects of television will be presented, including an address by the President of the Institution, Mr. Paul Adorian, M.Brit.I.R.E., on "The Future of Broadcasting." Many manufacturers in the radio industry will co-operate by displaying receivers, aerials, test gear and other television equipment at the exhibition.

A registration fee of 7s. 6d. will be payable by all taking part in the conference, which will be open to non-members of the Brit.I.R.E. Further details may be obtained from Mr. R. H. Garner, B.Sc.(Eng.), A.M.Brit.I.R.E., 66 Buchanan Drive, Cambuslang, Lanarkshire.

A Convention on Electrical Contacts is being held at the East Midland Centre of the Institution of Electrical Engineers at Loughborough College from April 7-9. Dr. W. G. Radley, C.B.E., Vice-President of the I.E.E., will open the Convention at 3 p.m. on April 7. A full programme of papers has been arranged, which will be divided into two parts on light duty contacts in theory and practice and heavy duty contacts, including contactors and sliding contacts.

There will be a registration fee of 2s. 6d. for each part of the Convention. Accommodation is available for about 80 men in the College Halls of Residence on April 7 and 8 for a guinea a day, including registration. Meals will also be provided at a reasonable charge, if booked in advance, for those not in residence at the Halls.

The Centre would welcome the participation of non-members of the Institution in the Convention, and further particulars can be obtained from the Honorary Secretary of the Centre, Mr. R. G. L. Ryan, c/o the Brush Electrical Engineering Co., Ltd., or from the programme organizers, Dr. J. H. Mitchell and Mr. R. C. Woods, Messrs. Ericsson Telephones, Ltd., Beeston, Nottingham.

Harwell Offers Course on Electronics. Physicists and engineers who wish to obtain specialized knowledge of electronic instruments used in nuclear physics, radiochemistry and work with radioisotopes, are being offered a course at the Atomic Energy Research Establishment, Harwell.

The course starts on Monday, May 19, and ends on Friday, May 23, and will deal specifically with the use of electronic equipment for detection and measurement of radiation. The mornings will be devoted to lectures and the afternoons to practical work. Design, use and maintenance of counters, D.C. pulse amplifiers, kicksorters, scalers and registers, and automatic equipment, will be included in the syllabus. Lecturers and demonstrators will be specialists from the Atomic Energy Research Establishment.

Candidates for the course will be expected to have a background knowledge equivalent to degree standard in physics or electronics. The number that can be accepted on the course is limited to 12, but if there is sufficient demand, further courses will be arranged. The building used will be the A.E.R.E. Isotope School, which is outside the security fence, and the subjects will be entirely unclassified.

The fee for the course is 12gns. Living accommodation (at Buckland House, near Faringdon, one of the A.E.R.E. Senior Staff Hostels), transport and morning and evening meals will be provided at a charge of 6 gns. Applications for admission to the course should be made as soon as possible to the Electronics Division, A.E.R.E., Harwell, Didcot, Berks.

Technical Writing. A series of ten lectures on "The Technique of Technical Writing" will be given by Mr. Geoffrey Parr, M.I.E.E., a director of Chapman and Hall, Ltd., at Norwood Technical College, West Norwood, London, S.E.27. The lectures will be held on Tuesday evenings, from 7 to 9 p.m., and will be divided into two parts, part one dealing with the subject of report writing, and part two concentrating on technical publication. Application forms for admission may be obtained from the Secretary of the College, and should be returned by March 12. The fee for the complete course is 15s., for part one only 12s. 6d., and for part two only 7s. 6d.

The Radio Communication and Electronic Engineering Association has elected Mr. K. S. Davies, B.Sc., A.M.I.E.E., who is the director of engineering of Murphy Radio, Ltd., as their Chairman for this year. Mr. C. G. White, director and general manager of the marine division of Kelvin and Hughes, Ltd., was elected Vice-Chairman. The 1951 Council of R.C.E.E.A. were re-elected to serve again.

Honorary Membership of the I.E.E. The Council of the Institution of Electrical Engineers have elected to Honorary Membership Sir Arthur Fleming, C.B.E., D.Eng., for his work in electrical engineering, and Sir Edward Appleton, K.C.B., G.B.E., M.A., D.Sc., LI.D., for his contributions to the field of pure and applied physics.

The Northern Radio and Television Exhibition will be held at the City Hall, Manchester, from April 23 to May 3, and will be organized by the Radio Industry Council. The B.B.C. will have a television studio in the exhibition, from which will be transmitted television performances, and arrangements are being made for the public to view rehearsals and performances. There will be a communal viewing gallery, where commercial television receivers will be demonstrated, as well as on the manufacturers stands. About fifty manufacturers of radio and television receivers, their associated equipment and components will be exhibiting.

The Engineering Centre, at 351 Sauchiehall Street, Glasgow, C.2, has arranged office facilities for a limited number of engineering firms' agents or representatives.

An area of about 1,000 square feet has been furnished with tables, desks, private lockers and telephone booths. The facilities offered include the use of the Centre's telephone numbers and address for the receipt of mail, messages, etc.

New Companies. The Edison Swan Electric Co., Ltd., has acquired the General Accessories Co. and British Mechanical Productions, Ltd., and both these companies are now operating as subsidiaries of Ediswan.

British Insulated Callender's Cables, Ltd. and the Loewy Engineering Co., Ltd. have formed a new company for development in the field of aluminium sheathed cables. The name of the new company is Alsheath, Ltd., and its offices are at Norfolk House, Norfolk Street, London, W.C.2.

Errata. On page 41 of the January, 1952 issue there appeared a misprint in Mr. Cutteridge's letter. Under "Insertion transfer function" it should read "With 4-terminal network inserted (Fig. 2). Load current $= I_2 = Eg \frac{-\Delta_{12}}{\Delta}$ etc."

We have been asked by Messrs. Allied Electronics, Ltd., to point out that there was an error in the information they supplied for their advertisement on page 41 of the same issue. The instrument advertised should have been described as a "peak to peak millivolter," not a "voltmeter."

MEETINGS THIS MONTH

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: March 27. Time: 6.30 p.m.
Held at: the London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.
Lecture: The Application of Magnetic Amplifiers to Industrial Measurement and Control.
By: H. M. Gale, B.Sc.

North-Eastern Section

Date: March 12. Time: 6 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Lecture: details to be announced later.

Scottish Section

Date: March 13. Time: 7 p.m.
Held at: the Natural Philosophy Department, The University, Drummond Street, Edinburgh.
Lecture: Radar as an Aid to Navigation.
By: N. J. Donald, B.Sc.
Date: March 14. Time: 7 p.m.
Held at: the Institute of Engineers and Shipbuilders, Glasgow.
Lecture: The Future of Broadcasting.
By: Paul Adorian, M.Brit.I.R.E.
(This meeting was postponed from February 27.)

South Midlands Section

Date: March 19. Time: 7.15 p.m.
Held at: the Exhibition Gallery, Public Library, Rugby.
Lecture: The Application of Magnetic Amplifiers to Industrial Measurement and Control.
By: H. M. Gale, B.Sc.

West Midlands Section

Date: March 25. Time: 7 p.m.
Held at: Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
Lecture: details to be announced later.

THE BRITISH SOUND RECORDING ASSOCIATION

Date: March 14. Time: 7 p.m.
Held at: the Royal Society of Arts, John Adam Street, London, W.C.2.
Lecture: Recording Characteristics.
By: P. E. A. R. Terry.

THE INSTITUTE OF PHYSICS

Electronics Group

Date: March 18. Time: 5.30 p.m.
Held at: the Institute's House, 47 Belgrave Square, London, S.W.1.
Lecture: The Physics of Transistors.
By: Dr. E. Billig.

Industrial Radiology Group

Date: March 21.
Held at: the Institute's House, 47 Belgrave Square, S.W.1.
Symposium: What is the Use of Standardization?

Scottish Branch

Date: March 11. Time: 7 p.m.
Held at: The University, Glasgow.
Lecture: Fundamental Standards.
By: B. W. Robinson.
Date: March 12. Time: 7 p.m.
Held at: The University, Edinburgh.
Lecture: as at Glasgow.

Manchester Branch

Date: March 21. Time: 7 p.m.
Held at: The University, Manchester.
Lecture: Spectroscopy at Centimetre Wavelengths.
By: Dr. B. Bleaney.

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.

Date: March 6.
Lecture: Post-Graduate Activities in Electrical Engineering.
By: W. J. Gibbs, M.Sc.(Eng.), D. Edmundson, B.Sc., R. G. A. Dimmick, B.Sc., and G. S. C. Lucas, O.B.E.
Date: March 10.
Discussion: Remote Measurement and Instrumentation.
Opened by: H. Horwood.
Date: March 13.
Lecture: Electronic Telephone Exchanges.
By: T. H. Flowers, M.B.E., B.Sc.

Measurements Section

Date: March 4.
Discussion: Design of Control Panels including Instrument Scales and Pointers.
Opened by: L. B. S. Golds and H. Murrell.
Date: March 18.
Lecture: The Application of Transductors as Relays to Protective Gear.
By: R. K. Edgley, M.Sc.(Eng.), and F. L. Hamilton, B.Sc.(Eng.).

Radio Section

Date: March 12.
Lecture: The Slot Aerial and its Application to Aircraft *and* A Survey of External and Suppressed Aircraft Aerials for Use in the High-Frequency Band.
By: R. H. J. Cary.
Date: March 24.
Informal Lecture: Radio-Controlled Models.

East Midland Centre

Date: March 11. Time: 6.30 p.m.
Held at: the East Midland Electricity Board Service Centre, Derby.
Lecture: The Determination of Time and Frequency.
By: H. M. Smith, B.Sc.

Cambridge Radio Group

Date: March 11. Time: 8.15 p.m.
Held at: the Cavendish Laboratory, Cambridge.
Lecture: An Investigation into the Mechanism of Magnetic-Tape Recording.
By: P. E. Axen, O.B.E., M.Sc.

Mersey and North Wales Centre

Date: March 17. Time: 6.45 p.m.
Held at: the Philharmonic Hall, Liverpool.
Faraday Lecture: Sound Recording—Home, Professional, Industrial and Scientific Applications.
By: G. F. Dutton, Ph.D., B.Sc.(Eng.).

North-Eastern Centre

Date: March 3. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Lecture: The Application of Transductors as Relays to Protective Gear.
By: R. K. Edgley, M.Sc.(Eng.), and F. L. Hamilton, B.Sc.(Eng.).
Date: March 11. Time: 7 p.m.
Held at: the City Hall, Newcastle-on-Tyne.
Faraday Lecture: Sound Recording—Home, Professional, Industrial and Scientific Applications.
By: G. F. Dutton, Ph.D., B.Sc.(Eng.).

North-Eastern Radio and Measurements Group

Date: March 3.
As in North-Eastern Centre.
Date: March 17. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Informal Lecture and Discussion.
By: G. A. V. Sowter, Ph.D., B.Sc.(Eng.).
Date: March 31. Time: 6.15 p.m.
Held at: King's College, Newcastle-upon-Tyne.
Lecture: The Design and Testing of an Electronic Servo-Simulator for a Hydraulic Remote Position-Controller.
By: F. J. U. Ritson, B.Sc., and P. H. Hammond, B.Sc.

North Midland Centre

Date: March 13. Time: 7 p.m.
Held at: the Town Hall, Leeds.
Faraday Lecture: Sound Recording—Home, Professional, Industrial and Scientific Applications.
By: G. F. Dutton, Ph.D., B.Sc.(Eng.).
Date: March 25. Time: 6.30 p.m.
Held at: the College of Technology, Leeds.
Discussion: The Teaching of Fundamentals.

North-Western Measurements Group

Date: March 18. Time: 6.15 p.m.
Held at: the Engineers' Club, Albert Square, Manchester.
Lecture: A Survey of Modern Methods of Presentation of Instrument Readings and Recordings.
By: L. B. S. Golds.

North-Western Supply Group

Date: March 25. Time: 6.15 p.m.
Held at: the Engineers' Club, Albert Square, Manchester.
Lecture: The Design of High-Voltage High-Power Mercury-Arc Convertors.
By: H. von Bertele, Dr.Ing., Dipl.Ing., and R. Tucker.

Northern Ireland Centre

Date: March 20. Time: 6.45 p.m.
Held at: the Sir William Whitla Hall, Belfast.
Faraday Lecture: Sound Recording—Home, Professional, Industrial and Scientific Applications.
By: G. F. Dutton, Ph.D., B.Sc.(Eng.).

Scottish Centre

Date: March 5. Time: 7 p.m.
Held at: the Heriot-Watt College, Edinburgh.
Lecture: Instruments for Use in the Microwave Band.
By: A. F. Harvey, D.Phil., B.Sc.(Eng.).

South Midland Centre

Date: March 5. Time: 6.30 p.m.
Held at: the Rugby College of Technology and Arts, Rugby.
Lecture: Technical Colleges and Education for the Electrical Industry.
By: H. L. Haslegrave, M.A., Ph.D., M.Sc.(Eng.).

South Midland Radio Group

Date: March 24. Time: 6 p.m.
Held at: the James Watt Memorial Institute, Great Charles Street, Birmingham.
Informal lecture: Stereophonic Sound Reproduction.
By: J. Moir and J. A. Leslie, B.Sc.

Southern Centre

Date: March 12. Time: 6.30 p.m.
Held at: the South Eastern Electricity Board Showrooms, Brighton.
Lecture: The Influence of Rectifier Harmonics in a Railway System on the Dielectric Stability of 33kV Cables.
By: S. B. Warder, E. Friedlander, Dr.Ing., and A. N. Arman, Ph.D.
Date: March 26. Time: 7.30 p.m.
Held at: the R.A.E. College, Farnborough.
Lecture: Supertension Cables.
By: J. Banks, M.Eng.

Western Utilization Group

Date: March 31. Time: 6 p.m.
Held at: the South Western Electricity Board Offices, Colston Avenue, Bristol.
Conference: Electricity as an Aid to Productivity.

Irish Branch

Date: March 20. Time: 6 p.m.
Held at: Trinity College, Dublin.
Lecture: Modulation—Some Fundamental Considerations.
By: T. P. Allen, M.Sc.

District Meetings

Date: March 3. Time: 7.30 p.m.
Held at: the New Inn, Sandling Road, Maidstone.
Film: Overhead Line Construction.
Discussion to follow.
Date: March 31. Time: 7.30 p.m.
Held at: the Royal Hotel, Norwich.
Informal lecture: The Nervous System as a Communication Network.
By: J. A. V. Bates, M.A., M.B., B.Chir

THE INSTITUTION OF ELECTRONICS

North-Western Branch

Date: March 19. Time: 7 p.m.
Held at: the College of Technology, Manchester.
Lecture: Electroencephalography with particular reference to the Ferranti Equipment.
By: W. Heaton.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: March 11. Time: 5 p.m.
Held at: the I.E.E., Savoy Place, London, W.C.2.
Lecture: The Control of External Major Works.
By: E. A. Scholey, B.Sc.

Informal Meeting

Date: March 26. Time: 5 p.m.
Held at: the Conference Room, 4th Floor, Waterloo Bridge House, London, S.E.1.
Lecture: The Provincial Exchange Area—Some Aspects of its Design and Development.
By: R. Thornton.

THE SOCIETY OF INSTRUMENT TECHNOLOGY

Date: March 25. Time: 7 p.m.
Held at: the Royal Society of Tropical Medicine and Hygiene, Manson House, Portland Place, London, W.1.
Lecture: The Design and Application of a Portable Electrostatic Watt Meter.
By: F. R. Axworthy, A.M.I.E.E.

THE TELEVISION SOCIETY

Date: March 13. Time: 7 p.m.
Held at: University College, London, W.C.1.
Lecture: The Fleming Memorial Lecture.
By: Professor H. M. Barlow.

Leicester Centre

Date: March 3. Time: 7 p.m.
Held at: the Leicester College of Technology, The Newarkes, Leicester.
Lecture: The Technique of Television Studio Lighting.
By: H. O. Sampson.
Date: March 31. Time: 7 p.m.
Held at: the Leicester College of Technology.
Lecture: The Design and Application of Television Gear.
By: R. Freeman and E. D. Groom.

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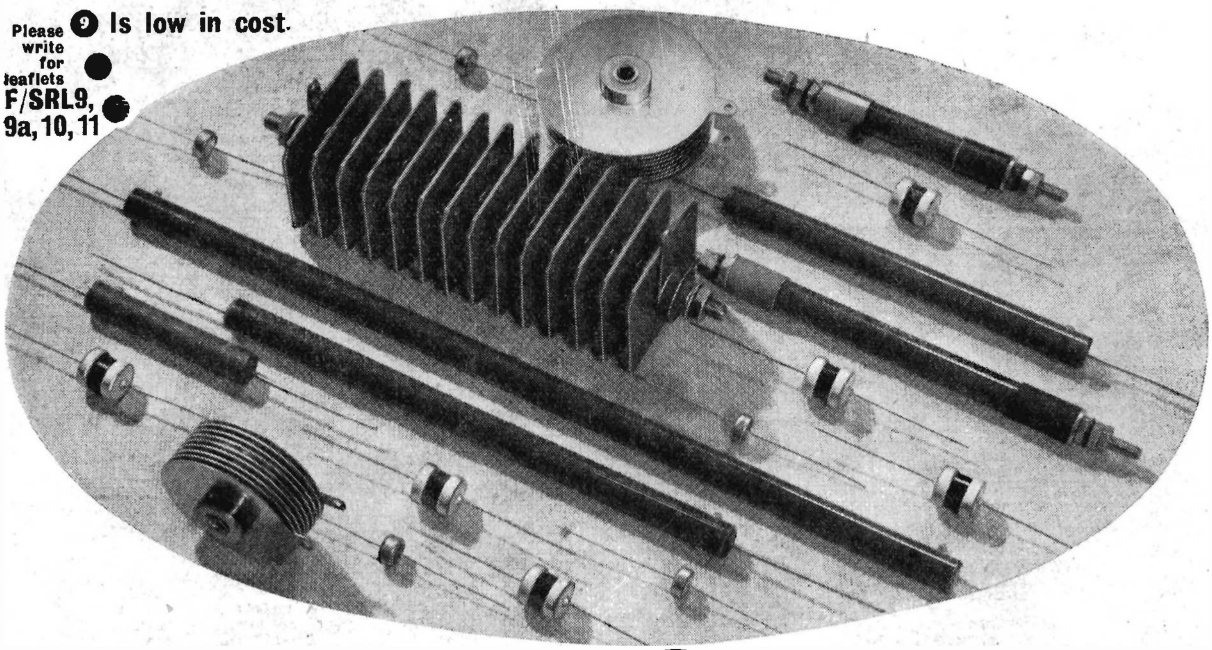

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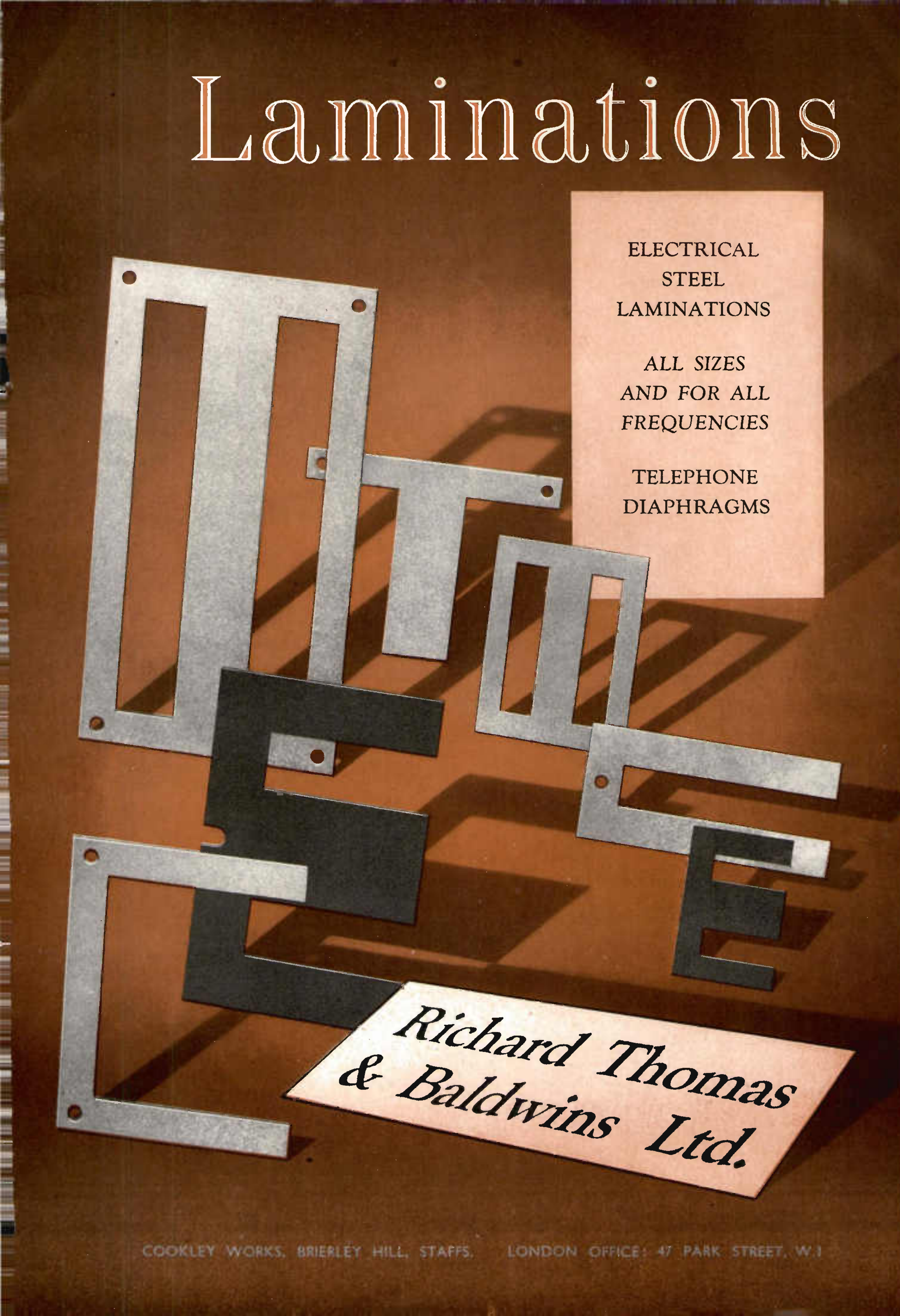

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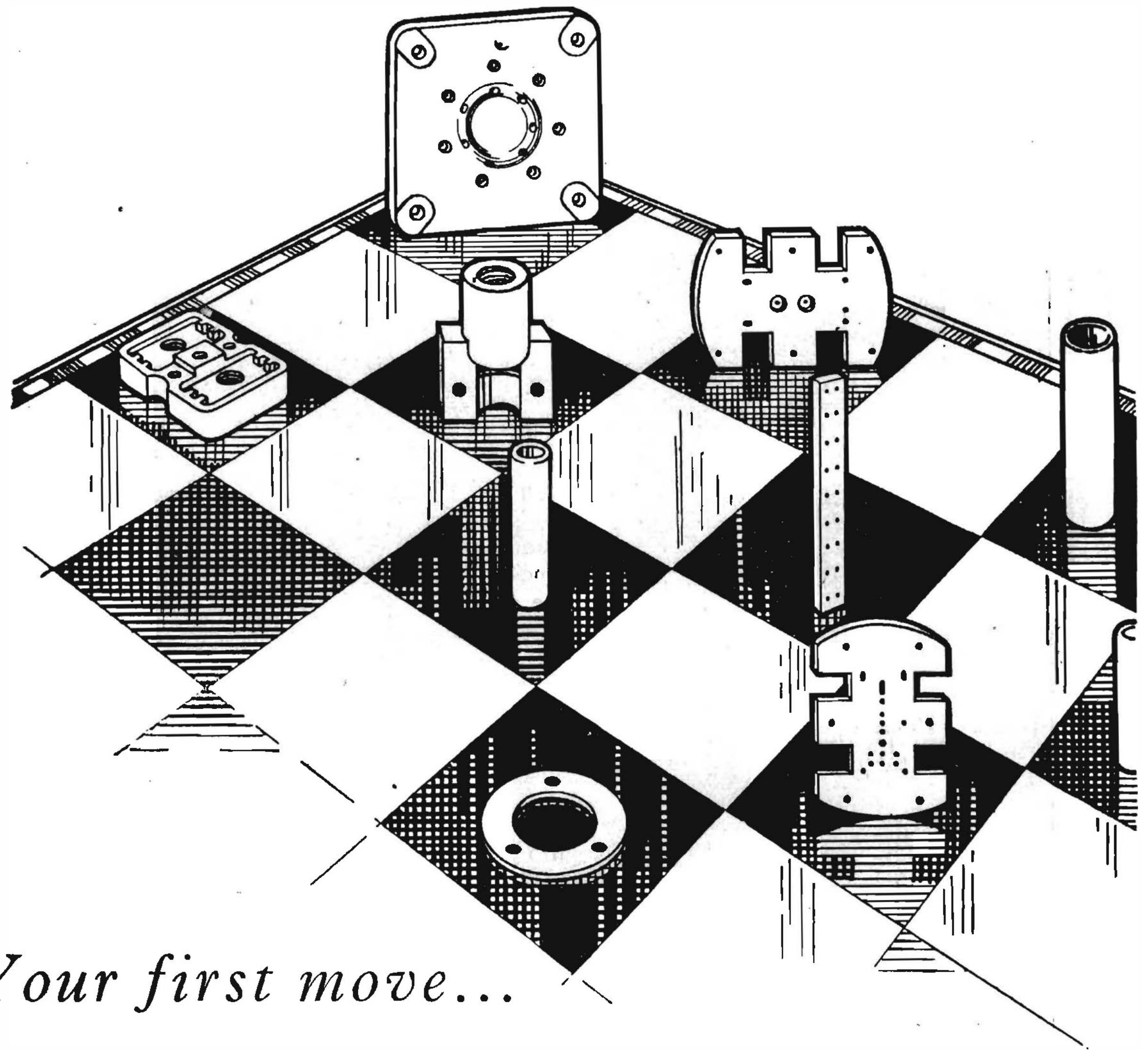

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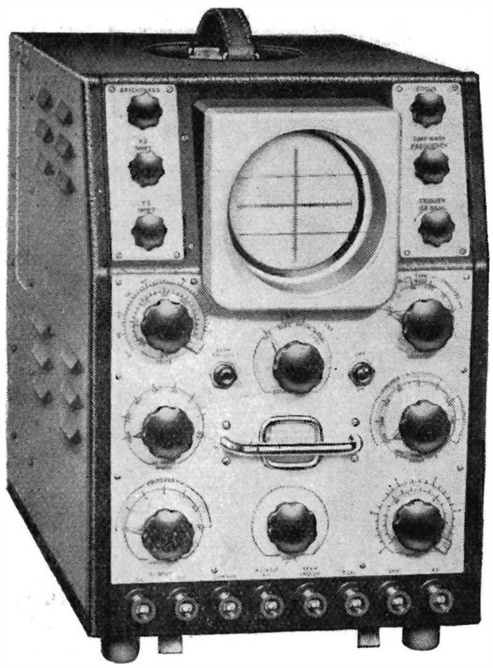


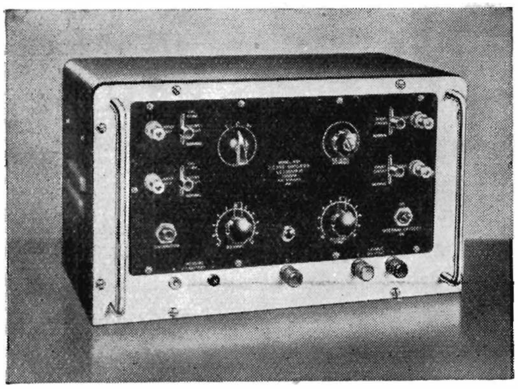
DOUBLE BEAM Model OSCILLOGRAPH 1049

This instrument is designed to meet the requirements of Industrial Concerns and Research Laboratories who require to measure phenomena of zero or very low frequency and to make photographic records of transients requiring a high photographic writing speed.

The Oscillograph incorporates the Cossor 4" flat-screen Double-Beam tube (type 89) operating at 2 K.V. but provision is made for operation at 4 K.V. when maximum spot brightness is required.

The amplifier circuits are direct-coupled throughout and provide independent amplifying channels for the Y1 and Y2 Beams with a gain of 900 and 25 respectively from zero frequency to 100 Kcs. Input signal voltages and frequency may be measured on either channel using the calibrated dials and special anti-parallax graticule. The direct-coupled time base is arranged to provide a repetitive and triggered scan with a time range of 1.5 seconds to 150 microseconds and can be synchronised from a pulse derived either from the internal work circuits or from an external source. A continuously variable control adjusts the amplitude of the sync. or trigger signal and selects the polarity of the pulse from which synchronisation is desired. A Z modulation system is incorporated for time-marking purposes. Stabilization against mains variations up to 10% is provided for amplifiers and cathode ray tube supplies. Long-period stability is reached within 5-10 minutes of switching on.

D.C. PRE-AMPLIFIER Model 1430



This instrument is a directly coupled pre-amplifier of high stability which has been designed for use with a further amplifier or with a recording device. Used in conjunction with a Cossor Model 1049 Double-Beam Oscillograph it will give a maximum overall gain of 45,000 and a maximum sensitivity of approximately 0.75 mV/cm. The frequency range is from D.C. to 30 Kc/s.

The input and output switching has been designed so that the instrument may be used to amplify either balanced or unbalanced input signals, and will provide a balanced or unbalanced output as required from either kind of input signal. The arrangement also makes it possible to check the amplifier balance and the setting up of the recording device without disconnecting the signal input or output leads.

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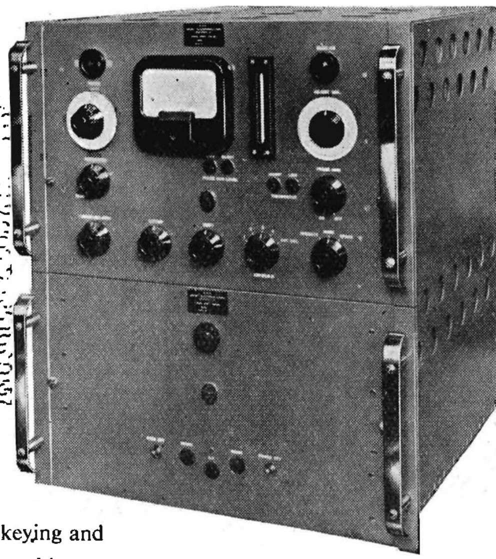
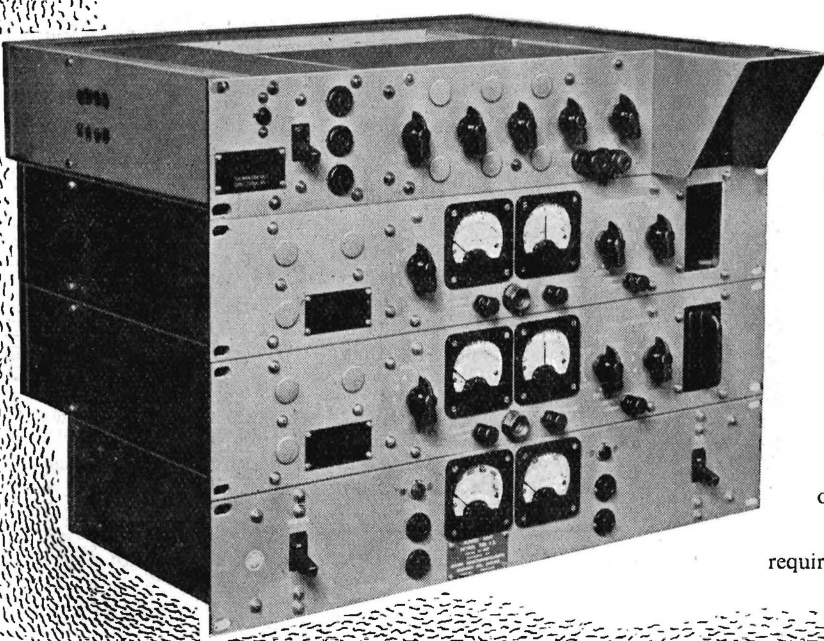
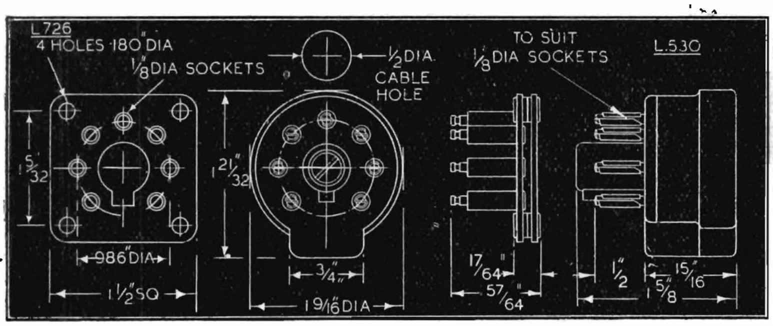
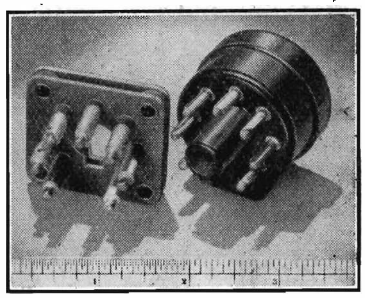




The "Belling-Lee" page for Engineers





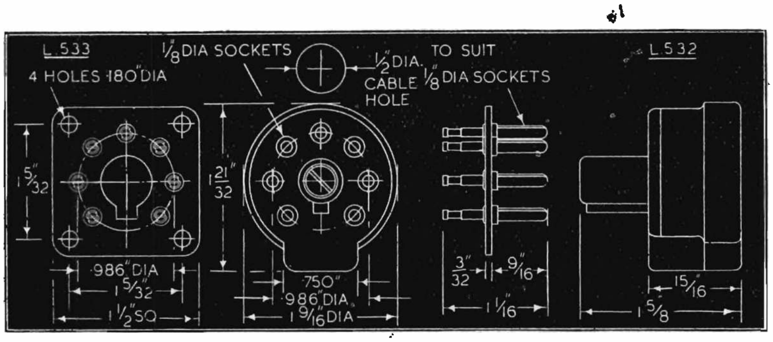
MULTI-CONNECTORS

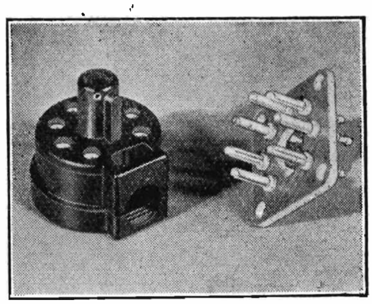
LIST NUMBERS

L.1258	**5-pole Flex Plug**
L.331	**5-pole Chassis Socket**
L.528	**5-pole Flex Plug**
L.529	**5-pole Chassis Socket**
L.550	**5-pole Flex Socket**
L.551	**5-pole Chassis Plug**

These connectors are particularly suitable for rack-built equipment and connecting power pack to chassis, amplifier to receiver, etc.; their application to the electronic and electrical industry is very wide and they are well worth using even with idle pins.

" O-Z " pins, semi-floating and silver-plated, giving low contact resistance, and facilitating soldering. A locating key is provided and no single pin can make contact until this is in its correct position.





L.530	**7-pole Flex Plug**
L.726	**7-pole Chassis Socket**
L.532	**7-pole Flex Socket**
L.533	**7-pole Chassis Plug**
L.1244	**10-pole Flex Plug**
L.332	**10-pole Chassis Socket**

The matching fit is exceptional, all pins making positive contact every time; can be coupled with eyes shut. The flex parts are all moulded from black phenolic material; single screw assembly; side entry to discourage pulling of cable. The socket panel is punched from synthetic resin-bonded paper with standard fixing holes. Plugs and sockets are provided with sensible solder spills. Chassis sockets have a shield panel raised well above the socket panel to ensure safety.

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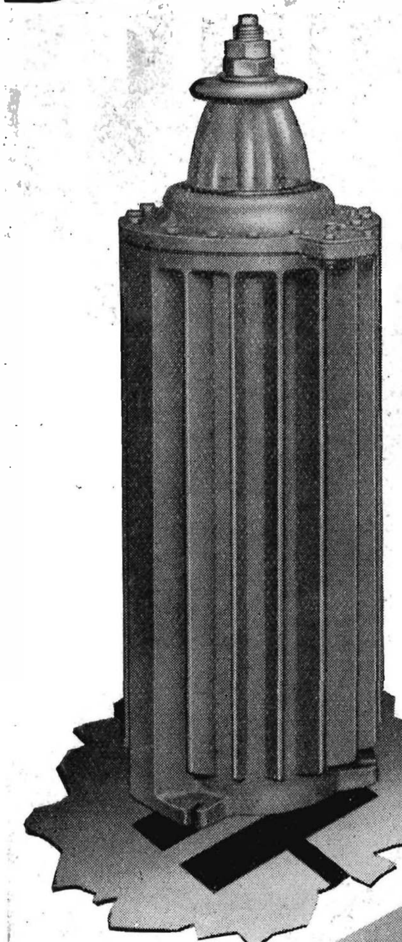

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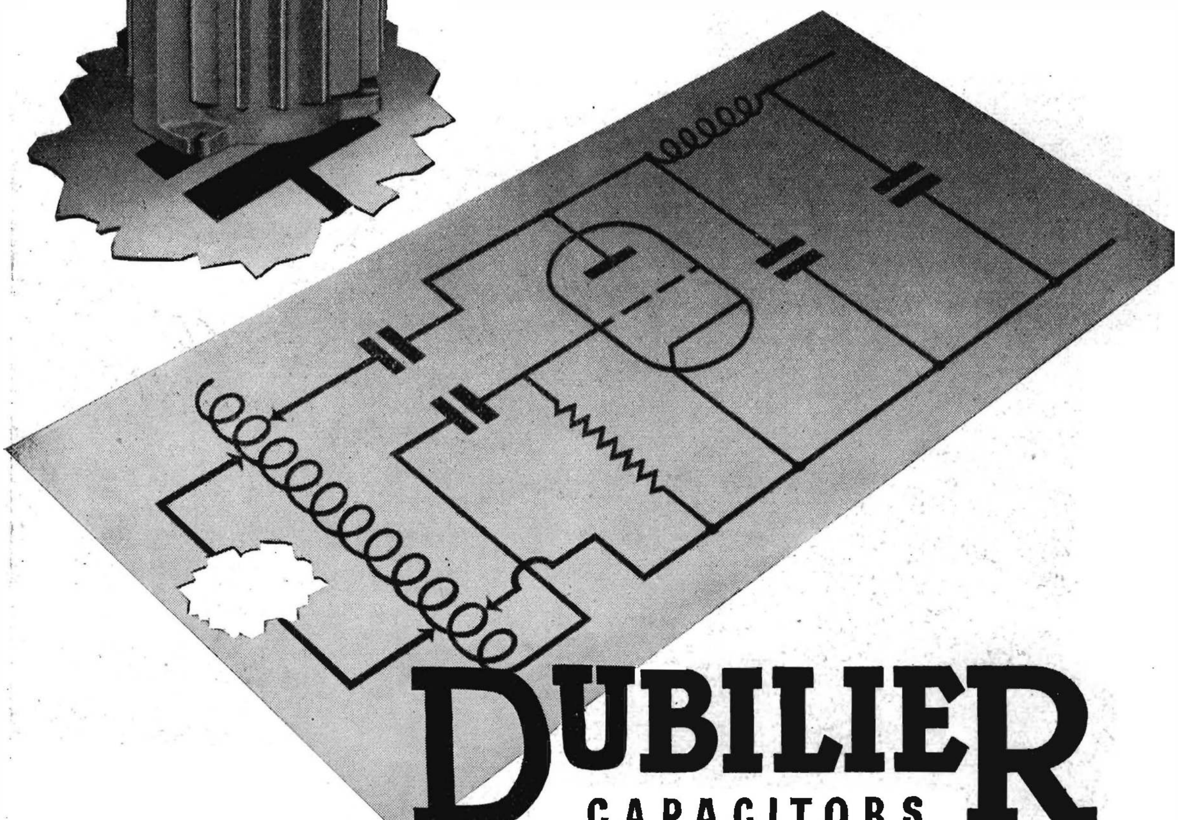

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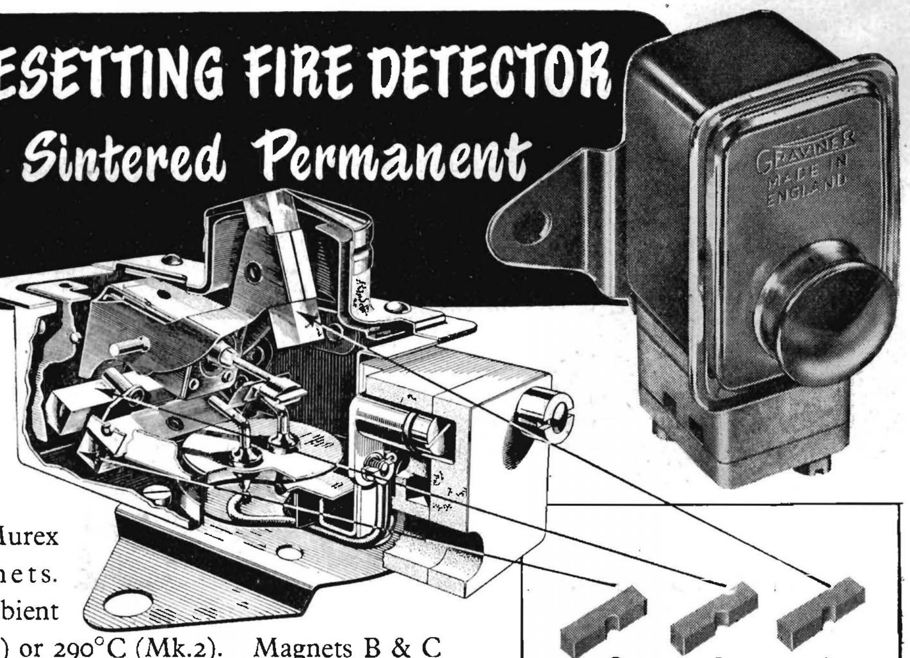

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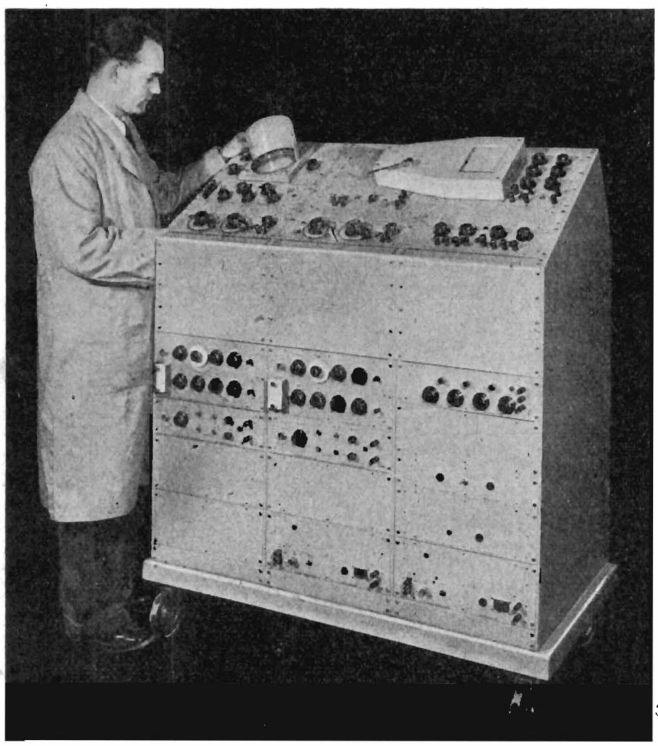

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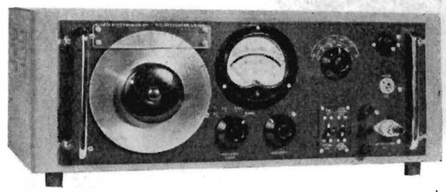

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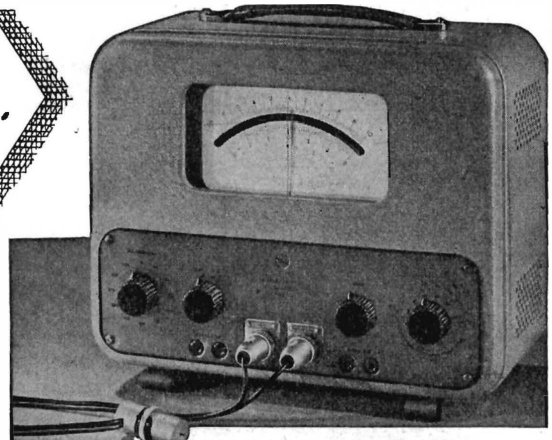

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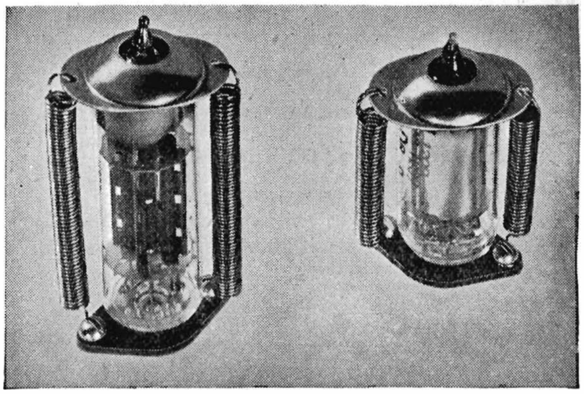

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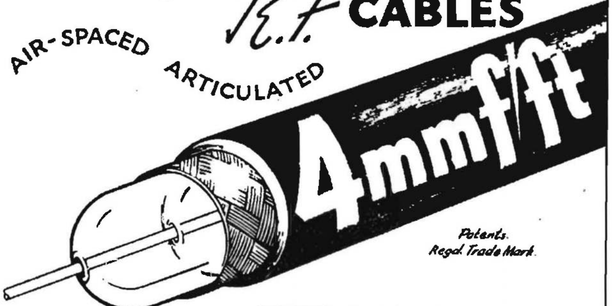

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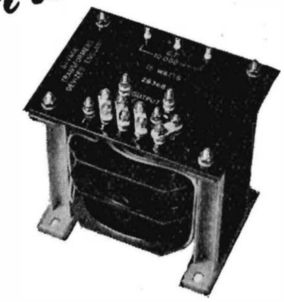

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