Electronic Engineering

JANUARY 1952

TWO SHILLINGS

CLASSIFIED ANNOUNCEMENTS

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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

ADMIRALTY. Vacancies exist for Electrical and/or Mechanical Engineering Draughtsmen in Admiralty Research and Development Establishments located in the vicinity of Weymouth, Portsmouth, Teddington (Middlesex) and Baldock, Herts. Draughtsmen experienced in light current, electro-mechanical, precision mechanical and electronic equipment are particularly needed. Candidates must be British subjects of 21 years of age and upwards, who have had practical workshop experience (preferably an apprenticeship) together with Drawing Office experience. Appointments will be in an unestablished capacity, but opportunities may occur for qualified staff to compete for established posts. The salaries offered, depending on age, experience, ability and place of duty, will be within the range £320-£560 p.a. Hostel accommodation is available at some Establishments. Applications, stating age and details of technical qualifications, apprenticeship (or equivalents) Workshop and Drawing Office experience should be sent to Admiralty (C.E.11, Room 88) Empire Hotel, Bath, quoting DM/R.D. Original testimonials should not be forwarded with application. Candidates required for interview (at London or Bath whichever is nearer) will be advised within two weeks of receipt of application. W 2328

APPLICATIONS are invited by the Ministry of Supply from Electrical and Mechanical Engineers for the following posts in the grade of Senior Scientific Officer at a Design Establishment, South-East of London. 1. Electrical Engineer for design and development of remote power controlled gear and servo systems D.511/51-A. 2. Mechanical Engineer for basic development of new projectiles and projectile systems. Duties require a knowledge of the physical aspects of applied mechanics, C.701/51-A. 3. Electrical Engineer for work on instrumentation for measurement of pressures, stresses, vibration, etc., and for the design of trials apparatus, D.512/51-A. Candidates should possess a 1st or 2nd class Honours Degree in mechanical or electrical engineering or equivalent qualifications and have had at least 3 years' relevant post-graduate experience. They must be at least 26 years of age. Salary will be assessed according to age, qualifications and experience within the range £720-£910. Rates for women somewhat lower. The posts are unestablished but carry F.S.S.U. benefits. Application forms obtainable from Technical and Scientific Register, (K) Almack House, 26-28 King Street, London, S.W.1, quoting appropriate Ref. No. Closing date 18th January, 1952. W 2349

APPLICATIONS are invited by the Ministry of Supply from Electrical Engineers and Physicists for the following immediate vacancies at a Research and Development Establishment in the South Midlands for work on Army radar equipment. Candidates should have experience, or interest, in development and experimental design work in the field of electronics including communications equipment, servo mechanisms and microwave techniques. Candidates with the qualifications outlined below are asked to make early applications for the vacancies. Scientific Officer Class. 1st or 2nd class Honours Degree or equivalent qualification in physics or electrical engineering. Grade and salary will be assessed according to age, qualifications and experience within the following ranges. (Candidates for the senior posts must have had at least 3 years' post-graduate research experience) Principal Scientific Officer (minimum age 31) £960 to £1,295. Senior Scientific Officer (minimum age 26) £720 to £910. Scientific Officer £380 to £620. Rates for women somewhat lower. Posts are unestablished but carry benefits under F.S.S.U. (Ref. No. A366/51/A). Experimental Officer Class. Minimum qualification is Higher School Certificate but other qualifications, e.g., Higher National Certificate or a Degree would be an advantage for some of the posts. Some experience in industry or a technical branch of the Forces is also desirable. Grade and salary will be assessed according to age, qualifications and experience within the following ranges. Senior Experimental Officer (minimum age 35) £742 to £960. Experimental Officer (minimum age 28) £545 to £695. Assistant Experimental Officer £240 (at age 18) to £505. Rates for women somewhat lower. Posts are unestablished. (Ref. No. D.523/51/A). Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26-28 King Street, London, S.W.1, quoting appropriate reference number. Closing date 14th January, 1952. W 2360

APPLICATIONS are invited by the Ministry of Supply for two posts in the instrumentation Department of the Royal Aircraft Establishment, Farnborough. (1) Principal Scientific Officer-Physicist to work on the improvement of existing techniques and investigation of new methods of photographic recording of experiments, including the use of long-focus lenses, and of colour photography. Candidates should have had considerable experience in optical and photographic work. A knowledge of the chemistry of photographic recording would be an advantage. (Ref. A367/51-A). (2) Senior Scientific Officer—Electrical Engineer or Physicist for experimental work in the development of magnetic recorders and associated electronic circuits. Candidates should have had considerable experience in electronic circuit work and some knowledge or experience of the principles and practice of magnetic recording would be an advantage. (Ref. A368/51-A). Candidates for both posts should have a 1st or 2nd class Honours Degree, or equivalent qualification, in the appropriate subject, with at least 3 years' post-graduate research experience. Salary will be assessed according to age, qualifications and experience within the ranges: Principal Scientific Officer (minimum age 31), £960 to £1,295. Senior Scientific Officer (minimum age 26), £720 to £910. Rates for women somewhat lower. Posts are unestablished but carry benefits under F.S.S.U. Application Forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26-28 King Street, London, S.W.1, quoting appropriate reference number. Closing date 26th January, 1952. W 2370

APPLICATIONS are invited by the Ministry of Supply from Physicists and Electrical Engineers for three posts in the Scientific Officer Grade, at an R.A.F. Signals Experimental Establishment in Norfolk. Candidates should have a first or second class Honours Degree in physics or electrical engineering or equivalent qualification with some experience on aerial problems, radio receivers and small transmitters for airborne or mobile use. Salary will be assessed according to age, qualifications and experience, within the range £380-£620. Rates for women somewhat lower. Posts are unestablished but carry benefits under F.S.S U. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26-28 King Street, London, S.W.1, quoting A380/51A. Closing date 14th January, 1952. W 2381

CITY OF COVENTRY Education Committee. Coventry Technical College. Principal: H. V. Field, B.Sc., Wh.Sch., M.I.E.E. Applications are invited for the following full-time teaching appointment in the Electrical Engineering and Physics Department. Lecturer in Electronics and Telecommunications. Candidates should be graduates or hold equivalent qualifications, have had appropriate industrial or service experience and preferably some teaching experience. Salary in accordance with Burnham Technical Scale (£900 × £25 × £1,000). Commencing date 1st January, 1952, or as soon as possible after that date. Application forms and full particulars of the above appointment obtainable from the undersigned, to whom the completed forms should be returned as soon as possible, and within 14 days of the appearance of this advertisement. W. L. Chinn, Director of Education. W 1375

ELECTRICAL ENGINEERS and Physicists are invited to apply for the following post at the Royal Aircraft Establishment, South Farnborough, Hants. 1. Principal Scientific Officer, to act as Deputy Leader of team engaged on the research and development of novel applications of radio techniques. The work is in the early stages and gives opportunity for the use of new ideas. Applicants should preferably have some experience in the planning and administration of research programmes and should be proficient in as many of the following fields as possible. (a) Centimetric and V.H.F. techniques including aerial systems, diffraction theory, duplex and R.F. bridge networks, frequency and phase modulation. (b) Circuit design including Information Theory. (c) Engineering of robust electronic and electro-mechanical devices (Ref. D501/51/A). 2. Senior Scientific Officer and Scientific Officer to assist in various aspects of the work detailed above. Post-graduate experience of original work, either theoretical or experimental, on the diffraction of Electro-magnetic waves would be an advantage for one post. (Ref. A345/51/A). 3. Senior Scientific Officer to work on novel forms of sighting equipment. Some experience of radar systems is essential but the emphasis of the work will be on the applications, rather than the design, of such systems. (Ref. A346/51/A). Candidates should have a 1st or 2nd class Honours Degree or equivalent qualifications in physics or electrical engineering. For the Principal and Senior posts some years of post-graduate research, in University or Industry, are required. Salaries will be assessed according to age, qualifications and experience within the ranges: P.S.O. (minimum age 31), £960 to £1,295. S.S.O. (minimum age 26), £720 to £910. S.O., £380 to £620. Rates for women somewhat lower. Posts are unestablished but carry benefits under F.S.S.U. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26-28 King Street, London, S.W.1, quoting appropriate reference number. W 2332

ENGINEER required by Ministry of Supply in London. Qualifications: British, of British parentage; recognised engineering apprenticeship and either be corporate member of one of the Institutions of Civil, Mechanical or Electrical Engineers or have exempting qualifications. Should have a knowledge of radio and/or radar and had production experience in the following: Thermionic test gear and valves, light engineering and press work, and injection moulding. Duties: Assist in planning and progressing production of electronic fuses and specialised thermionic devices. Salary: Within the range £600-£900 per annum. Unestablished, periodical competitions for established pensionable posts. Application forms from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26-28 King Street, S.W.1, quoting Ref. D516/51A. Closing date 12th January, 1952. W 2353

ENGINEERS required by Ministry of Supply in London. Must be British of British parentage with regular engineering apprenticeship and either be corporate members of one of the Institutions of Civil, Mechanical or Electrical Engineers, or have exempting qualifications. Post One: (Ref. C.690/51A) Production planning of chemical and mechanical propulsion units (rocket motors, pulse jet engines, etc.), ancillary equipment (fuel and booster pumps, mixing and pressure valves, igniters, etc.). A knowledge of solid and liquid propellants is required together with experience of sheet metal fabrication. Post Two: (Ref. C.691/51A) Production planning of Guidance equipment (electronic, air and ground guidance apparatus; valves, fuses, test gear) and Control equipment (mainly gyroscopic and servo-mechanisms) for guided weapons. Candidates should preferably have experience on miniature and sub-miniature equipment, and production in the radio industry. Salary: Within the range £600-

OFFICIAL APPOINTMENTS (Cont'd.)

£900 p.a. Unestablished, periodical competitions for established pensionable posts. Application forms from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26-28 King Street, London, S.W.1. Quoting appropriate Reference Number. Closing date 19th January, 1952. W 2333

MINISTRY OF SUPPLY require Engineer for establishment at Hayes, Middlesex. Qualifications: British of British parentage; regular engineering apprenticeship and either be corporate member of one of the Institutions of Civil, Mechanical or Electrical Engineers or have exempting qualifications; sound knowledge of electronic theory and practice and familiarity with modern techniques. Knowledge of Service usage and experience of methods used for proof of ammunition (particularly fuses) an advantage. Duties: Control section responsible for the technical direction of inspection of mass produced miniature electronic devices. Salary: Within the range £900-£1,200 p.a. Unestablished, periodical competitions for established pensionable posts. Application forms from the Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26-28 King Street, S.W.1, quoting Ref. D518/51A. Closing date 12th January, 1952. W 2354

NATIONAL COAL BOARD. Applications are invited for the undermentioned superannuable appointments at the Central Research Establishment, Stoke Orchard, near Cheltenham. (i) Scientists II or III for research in the Telecommunications and Light Electrical Engineering fields. Candidates should have an Honours Degree in electrical engineering or physics, with good knowledge of electronic techniques. Appointment will be as Scientist Grade III on the scale £445 × £25 to £845 per annum, or Scientist Grade II on the scale £645 × £30 to £995 per annum, according to ability and experience. At least three years' research experience is essential for appointment as Grade II. (Ref. TT/400). (ii) Electronics Engineers to design and construct electronic devices for research. Appointment will be as Scientific Technologist Grade I on the scale £435 × £20 to £655, or Senior Scientific Technologist on the scale £670 × £25 to £820. Good experience and knowledge of circuitry is essential for appointment as Senior Scientific Technologist. (Ref. TT/401). Apply in writing, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates) to National Coal Board, Establishments (Personnel), Hobard House, Grosvenor Place, London, S.W.1. marking envelope with the relevant TT Reference Number quoted above. Original testimonials should not be forwarded. Closing date 12th January, 1952. W 2329

RADAR AND ELECTRICAL Control Equipment Technicians wanted for work of National Importance. Vacancies exist in London and Home Counties. Good prospects exist for advancement. Salary scale £460 × £20 p.a. rising to £570 p.a. Apply giving full details of qualifications, experience and area preferred, to: IA.A. Group Workshop R.E.M.E., Shrapnel Barracks, Woolwich, S.E.18. W 2356

SITUATIONS VACANT

ALWYN ISHERWOOD LIMITED. require T.V. engineers for bench and field service. If you want good pay with prospects under ideal operating conditions, and you are master of your craft, contact the Service Manager, Alwyn Isherwood Limited, 91/95 Westgate, Wakefield. Tel. 3196/7. Expenses will be paid for all applicants selected for interview. W 1373

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.

AN EXPERIENCED electrical engineer or physicist is required by the Research Laboratories of The General Electric Co. Limited, at their Stanmore Laboratories to take responsibility for the work of a number of men engaged on research and development on circuits for the generation and handling of non-sinusoidal waveforms such as are used in timebases, differential analysers and digital and analogue computers. Applicants preferably between 28-35 should have good Honours Degrees and should be able to produce evidence of ability for original work and inventiveness in the form of published work or patents. The appointment is in connexion with a major guided weapon project for defence and offers good prospects and starting salary. Applications should be sent to the Staff Manager (Ref. GBLC/307), G.E.C. Research Laboratories, North Wembley, Middlesex. W 2375

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

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

APPLIED MATHEMATICIAN required. Applications invited from Graduates (male and female) for work of national importance. Ability to do original work as well as numerical evaluation of problems and test data on a statistical basis required. Experience of servo mechanisms desirable but not essential. Write with full details of age, experience and salary required to the Personnel Manager, Sperry Gyroscope Company Limited, Victoria Road, Feltham, Middlesex. W 2388

A VACANCY exists for a Senior Radio Engineer with mechanical as well as electrical design experience to take charge of the Broadcast receiver design group of a leading Radio Manufacturer. Applicants will be required to produce evidence of responsible experience and successful development work in this field. A salary will be paid in keeping with the importance of the appointment. Apply in confidence to Box No. W 2371.

A VACANCY exists for a Broadcast Receiver Engineer experienced in mechanical as well as electrical design in this field and capable of taking full responsibility for the design of individual radio receivers. Salary in accordance with qualifications. Apply in confidence to Box No. W 2372.

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

CALIBRATION ENGINEER required to supervise the maintenance of electrical test gear for valve and CRT making plant. Salary according to experience. Applicants should apply in person or write to Personnel Department, E.M.I. Factories Limited, Hayes, Middlesex. W 2369

CHIEF INSPECTOR required for Capacitor manufacturers' London factory. Good salary and prospects for first class man with sound technical qualifications. Position is pensionable. Write giving full details of age and experience to Box No. W 2335.

DESIGN ENGINEERS. (Ref. 862A) required by The English Electric Company Limited, Luton, for work on flight simulators in connexion with guided weapon development. Degree or H.N.C. essential and previous experience of electromechanical and electronic analogue computing desirable. Applications stating age, technical qualifications and experience to Central Personnel Services, 24 Gillingham Street, London, S.W.1, quoting reference. W 2263

DESIGNER, preferably 24-30 years with good Honours Degree in Mechanical Engineering, is required for the Drawing Office of the Stanmore Laboratories of The General Electric Co.. Ltd., for work associated with Guided Missiles and Airborne Radar Equipment. An excellent opportunity for a capable man possessing initiative and originality and with good practical experience and fundamental knowledge. Electrical experience not essential. Applications should be sent to the Staff Manager (Ref. GBLC/286), G.E.C. Research Laboratories. Wembley, Middlesex, stating age and record. W 2362

DEVELOPMENT ENGINEER required for well-known firm of electrical instrument makers situated in North London. Man with good technical and mechanical knowledge for experimental work. Apply Box No. W 2211.

DEVELOPMENT ENGINEER 23/30, education to H.N.C. or higher, for old established firm of precision electrical instrument makers in Beckenham area. The work is in connexion with laboratory electronic instruments at audio and supersonic frequencies. Experience in electrical measurements desirable. Write giving full details of training, experience and salary required to Box No. W 2342.

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

DEVELOPMENT ENGINEERS required by firm in N.W. London manufacturing an extensive range of industrial instruments and controls. Candidates should have a good theoretical background, preferably with a Degree or equivalent in physics or electrical engineering and should have some experience of the development or testing of process control instruments. The starting salary will be according to the experience of the applicant ranging from £400 per annum for Junior Engineers to £650 per annum for specially qualified applicants. Write Box No. W 2285.

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BRITISH INSULATED CALLENDER'S CABLES LIMITED. Telecommunications Research Laboratory, Kirkby, Nr. Liverpool. The Laboratory is engaged in research and development work on all aspects of cable manufacture and testing. Progressive opportunities exist for enthusiastic technical staff of all grades. Applications will be welcomed from Telecommunications Engineers, Electrical and Mechanical Engineers, Electronics Engineers, Senior Mathematicians, Physicists. Candidates will be considered for interview on the basis of their letters of application, which should be addressed to: The Staff Officer, British Insulated Callender's Cables Limited, Prescot, Lancs. W 2366

SITUATIONS VACANT (Cont'd.)

DIGITAL COMPUTORS: There are vacancies in the Computer Section of Ferranti Limited for the following:- (a) Circuit Engineer, experienced in pulse or radar circuits with an interest in the development of circuits associated with high speed mechanical devices. Some mechanical engineering background is desirable but not essential. Ref. D.C.C. (b) Mechanical Engineer with wide experience in design of precision high speed mechanical devices. An interest in electronics is preferred but not essential. Ref. D.C. Mech. (c) Engineer with wide experience of magnetic recording equipments required for interesting new project. Ref. D.C. Mag. Salary for the above posts will be, in accordance with experience and ability, in the range £520-£1,000 per annum. Contributory Pension Scheme in operation. Forms of application from Mr. R. J. Hebbert, Staff Manager, Ferranti, Ltd., Hollinwood, Lancs. W 2346

DRAUGHTSMAN required by firm of Radio Manufacturers for the design and development of domestic Radio and Television in all its aspects. Must be a first class man able to work with the minimum of supervision. Box 110, Gordon House, 75 Farringdon Street, London, E.C.4. W 2393

DRAUGHTSMEN (Senior and Junior) required in Research Department for design and detail work on special Radar and Electro-mechanical equipment. West London area. Write giving full particulars of experience, age and salary required to Box A.E. 693, Central News Limited, 17 Moorgate, London, E.C.2. W 2386

DRAWING OFFICE INSTRUCTOR required, January, 1952. Duties consist mainly of instruction in Engineering Drawing, Mathematics and Mechanics to draughtsmen apprentices. Applicants should have served an engineering apprenticeship with subsequent Drawing Office experience, preferably in light mechanical or electronic engineering. Instructional experience is desirable but not essential. Salary £525-£625 per annum. Applications to:- The Principal, E.M.I. Institutes, 10 Pembridge Square, London, W.2. W 2337

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

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

ELECTRICAL ENGINEER, preferably with an Honours Degree and some radio or telecommunications experience is required for experimental work on specialized radio equipment. Apply to the Staff Manager (Ref. GBLC/0272) Research Laboratories of The General Electric Co., Ltd., Wembley, Middlesex, giving age and record. W 2359

ELECTRICAL ENGINEERS and Physicists or Mechanical Engineers with experience of electrical work required by large manufacturer of light electrical engineering products situated in East London. Applicants should have technical qualifications of Degree standard and have had some years' experience of development work. Permanent positions with exceptional prospects will be offered to men possessing the right qualifications. Kindly state full details of experience to Box No. W 2344.

ELECTRONIC DEVELOPMENT ENGINEER required to join staff of expanding Laboratory team working on Government and Industrial contracts. Experience of video techniques essential; experience of waveguide techniques desirable. Salary £700 p.a. Good opportunity for energetic man. Write stating experience to Technical Director, Winston Electronics Limited, 1 Park Road, Hampton Hill, Middlesex. W 1385

ELECTRONIC ENGINEER or Physicist required for installation and service of electron microscopes. Necessary training given to man with suitable technical background and practical skill which should include some experience of high voltage work, scientific instruments and vacuum physics. Degree desirable but not essential. Applicants should be able to appreciate users' research problems and willing to travel throughout Europe from company headquarters in London. Excellent prospects and liberal expenses. Please state age, education, experience and starting salary required. Box No. W 2379.

ELECTRONIC ENGINEERS are invited to apply for an appointment in the Research Laboratories of the English Electric Valve Co. Ltd., at Chelmsford, to work on the development of experimental television circuits. Applicants should have considerable experience of this type of work, with particular reference to camera tubes, together with a Science Degree or equivalent qualifications. Remuneration will be dependent on qualifications and experience and the position will offer ample scope for advancement. Please write giving full particulars and quoting Ref. 440C to Central Personnel Services, 24/30 Gillingham Street, London, S.W.1. W 2345

ELECTRONIC ENGINEERS required in the Weybridge district. Experienced in installation, inspection and testing of electronic equipment to Ministry standard. Write stating age, experience, qualifications and salary required to Box P.812, Willings, 362 Gray's Inn Road, London. W.C.1. W 2256

ELECTRONIC ENGINEERS REQUIRED for development work in 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 No. A.C. 67297, Samson Clarks, 57-61 Mortimer Street, London, W.1. W 2291

ELECTRONIC PRODUCTION ENGINEER required with thorough knowledge of planning and technical control in factory (both prototype and specialized production). Must have sound practical background and able to make and maintain factory set-ups incorporating valve voltmeters, oscillators, wave analysers, etc. Qualifications to H.N.C. standard. Preference given to applicant with experience on gyroscopic/electro-mechanical precision instrument manufacture. Write stating age, experience and salary required to: The Personnel Manager. Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middx. W 2348

ENGINEERS are required for the development of high grade test equipment in connexion with the manufacture of automatic pilots and aircraft instruments. This work involves the application of electronic techniques over a frequency range from zero to approximately 100 Kc. c.p.s., together with light electrical and mechanical engineering. Applicants having experience of applied measurements in one or more of the above mentioned engineering fields will naturally be preferred but the foremost qualification is a sound appreciation of fundamental engineering principles. Salary according to qualifications and experience. Please quote reference 1/EN. Write: Personnel Manager, S. Smith and Sons (England) Limited, Bishops Cleeve, Nr. Cheltenham, Glos. W 2383

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 Department, The British Thomson-Houston Co., Ltd., Rugby. W 2391

ENGLISH ELECTRIC VALVE CO. LIMITED. 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. 497D, to Central Personnel Services, English Electric Co., Ltd., 24/30 Gillingham Street, London, S.W.1. W 2343

ELECTRONIC TECHNICIAN of H.N.C. standard. Required to construct and prove experimental equipment for a progressive manufacturing Company situated in the North West London Area. Good prospects, 5-day week. Apply giving full particulars of experience and salary required. Ref. MA2/100. Box No. W 2382.

EXPERIENCED ELECTRONIC ENGINEERS required for interesting development work on a number of projects. Applicants should have a sound theoretical background with several years' experience in the design and engineering of prototype electronic equipment. The posts are for permanent staff and offer good salaries and prospects. Please write giving full details and quoting ED/63, to Personnel Department, E.M.I. Engineering Development Ltd., Hayes, Middlesex. W 2357

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

FURZEHILL LABORATORIES LTD., Boreham Wood, Herts., have vacancies for Electronic Engineers. Applications are invited for the Cheltenham Laboratory which is engaged mainly on the development of servo systems for aircraft and industrial purposes and for the Boreham Wood Laboratory handling Laboratory Measuring Instruments. Posts are available for Project Engineers who should preferably hold an Honours Degree; Development Engineers of Degree standard, Junior Engineers and Design Draughtsmen. Salaries range from £350-£1,200 p.a. and houses are available to selected applicants in the Cheltenham area. W 2390

INDUSTRIAL RESEARCH. Applications invited from Physicists or Electrical Engineers for position of Senior Development Engineer to London Company manufacturing Capacitors. Good degree and some research experience will be required. Good salary with pension rights for first class men. Write giving full details of age and experience to Box No. W 2334.

INSPECTORS Mechanical and Electronic. Good rates of pay, plus staff appointments in cases of exceptional ability. Canteen facilities, social club and congenial working conditions. Apply in writing or personally to Personnel Officer, Decca Radar Co. Limited, Shannon Corner, Kingston-by-Pass, New Malden, Surrey. W 2320

INSTRUMENT ASSEMBLERS with some electrical knowledge required, also test room assistants, for well-known instrument Company situated in North London. Good working conditions and canteen. Apply Box No. W 2210.

INTERESTING and varied work on the development of special instruments is offered to young, qualified Physicists and Electronic Engineers, preferably with 2-3 years' industrial experience. Write, stating salary required, to Nash & Thompson, Ltd., Oakcroft Road, Tolworth, Surrey. W 2351

JUNIOR ENGINEER required for high priority electronic and light mechanical work in Equipment Laboratory of Surrey factory. Previous experience is essential, and technical training to Higher National Certificate is desirable. Salary according to experience and qualifications. Staff Pension Scheme in operation. Write, giving full details to Box No. W 2336.

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

CLASSIFIED ANNOUNCEMENTS
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LABORATORY ASSISTANT required for instrument section. Previous experience in making and repairing indicating instruments essential. Higher National Certificate or equivalent qualification would be an advantage, but is not essential. Apply in writing giving full details of training and experience to the Staff Manager (Ref. GBLC/G/921), Research Laboratories of the General Electric Co. Limited, East Lane, Wembley, Middlesex. W 2330

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

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

PHYSICISTS or Light Current Engineers with knowledge of circuit design and mathematical ability to work on Flight Simulators in connexion with guided weapon development. Degree or H.N.C. essential and previous experience of electro-mechanical and electronic analogue computing desirable. Applications, stating age, technical qualifications and experience, quoting Ref. 862B, should be addressed to Central Personnel Services, English Electric Company Ltd., 24/30 Gillingham Street, London, S.W.1. W 2389

PHYSICISTS OR PHYSICAL CHEMISTS required for laboratory in Northamptonshire, to carry out varied and interesting work on new ceramic and metallic materials. Applicants should have a good science degree and be familiar with techniques for measuring magnetic and dielectric properties. Experience in designing radio and electronic components from these materials an advantage. Salary £450-£650 according to qualifications and experience. Box No. W 2051.

PLANNING ENGINEERS with jig and tool design and estimating experience required for Electronic Division of E. K. Cole, Ltd., Malmesbury, Wilts. Apply Personnel Manager, stating age, experience and salary required. W 2352

RADIO MECHANICS required for work on centimetre equipments at Stanmore. Previous experience essential. Progressive staff positions. Five-day week. Write giving full details of age, experience and qualifications to the Staff Manager (Ref. GBLC/G/44), Research Laboratories of the General Electric Co. Limited, North Wembley, Middlesex. W 2180

REPRESENTATIVE for leading radio component manufacturing firm required to deal direct with radio manufacturers. Some technical knowledge desirable but not essential. Age 25-30 years. Reply stating experience and salary required to Box No. W 1388.

REQUIRED by an old established firm at their Research Laboratories, Borehamwood. Senior Draughtsmen for design of specialized Electronic Equipment or Mechanical and Electrical precision devices. Sound general engineering and practical experience. Higher National Certificate standard preferred. Must be capable of undertaking design work calling for originality and initiative. Salary up to £625. Five-day week of 39½ hours. Apply Box No. W 140.

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

SCUNTHORPE HOSPITAL MANAGEMENT COMMITTEE. Radiotherapy Centre. There is a vacancy for a Technician in the Physics Department in the above Centre at the War Memorial Hospital, Scunthorpe, for duties connected with the maintenance and modification of X-Ray Sets and other electrical and electronic apparatus in the Department. Applicants should have experience of high kilo-voltage work and should be at least 24 years of age. Experience of electrical fitting would be an advantage. An electrical qualification of the standard of Ordinary National Certificate is desirable. The conditions recommended by the British X-Ray and Radium Protection Committee are operative. Further particulars may be obtained from the Physicist. Salary scale £410 x £15(3) x £20(1) to £475. The post is subject to the provisions of the National Health Service Superannuation Scheme and new entrants will be required to pass a medical examination. Applications giving details of education, qualifications and experience with names of two referees must reach the undersigned by 15th January, 1952. S. Lord, Secretary. W 2361

SENIOR CIRCUIT ENGINEER is required by the English Electric Co., for employment in the London area. Experience of designing time bases, stabilized power packs and cathode ray monitoring circuits is essential, a Degree and an interest in production development is desirable. A good salary will be paid to the right man for this responsible position. Write giving full details, quoting ref. 921 to Central Personnel Services, English Electric Co. Limited, 24-30 Gillingham Street, London, S.W.1. W 2248

SENIOR DRAUGHTSMEN: Metropolitan-Vickers Electrical Co. Ltd., require for their Trafford Park works, a number of senior draughtsmen preferably with experience in Radio and Radar equipment. For qualified men these jobs are permanent, five-day week under good conditions. Apply in writing stating age, experience, qualifications, salary required, etc., marking envelopes "Radio D.O." to Personnel Manager, Metropolitan-Vickers Electrical Co. Limited, Trafford Park, Manchester 17. W 2140

SENIOR ENGINEER required to undertake development work on low frequency iron cored components. Previous experience in this subject is essential, and a Degree or equivalent would be an advantage. The salary will be in accordance with qualifications and experience. Apply in writing to Advance Components Limited, Back Road, Shernall Street, Walthamstow, E.17. W 2269

SENIOR TELEVISION Development Engineer required by well known Radio and Television Manufacturer in London area. Applicant must have a wide experience in development for mass production of modern commercial radio and television receivers. A good salary will be paid to a person possessing drive and organising ability and capable of carrying through projects from development to production stages, under the supervision of the Chief Engineer. Kindly state full particulars of technical education and experience to Box No. W 2365.

SERVO DESIGNER, aged 30-40 required, salary £1,000-£1,500 according to experience. First or Second Class Honours Degree in Mathematics, Mechanical or Electrical engineering required but applicant should be well versed in all three branches. Considerable experience required in the design of servo systems preferably for aircraft. The applicant, who will be interviewed in London, will be responsible for the control of development projects comprising electrical and hydraulic servo flying controls. W 2255

SEVERAL ELECTRONIC ENGINEERS or Physicists are required, who have graduated in Physics or Telecommunications and have two or three years radar experience, to take charge of the development of particular sections of a project involving radar. The work includes design of pulse generators, timing wave form oscillators, electronic computors, V.H.F. transmitters, and receivers and servo systems. In addition Technical Assistants are needed with H.N.C. or equivalent qualifications. All the positions available are for work of high interest in a new and expanding field. Applications, which will receive prompt attention should give the fullest details of education and professional experience with appropriate dates. Apply Employment Manager, Vickers-Armstrongs Limited (Aircraft Section), Weybridge, Surrey. W 2271

TECHNICAL ASSISTANTS required for interesting Laboratory and Field work connected with Guided Missiles Project. Applicants to be between 20 and 35 years of age with, at least, National Certificate (Electrical) or equivalent. Experience of R.F. technique up to 500 mc. would be an advantage. Full particulars to Box No. W 2191.

TECHNICAL WRITER, experienced in compiling matter for publication in Radio and Television Service Manuals, Instruction Leaflets etc., required for Engineering Department of Enfield Factory. Reply stating age, qualifications, etc., to Box No. W 2355.

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

TELEPHONE ENGINEER required for important technical commercial post in large organisation of world repute. Appointment based on London offers exceptional opportunities for exceptional man. Applicants must have an engineering or scientific Degree and thorough experience of carrier technique. Commercial and C.C.I.F. experience would be advantageous. Adequate time will be allowed for successful applicant to familiarise himself with Company's activities, including some months abroad before taking charge of new project. Salary according to experience. Applications will be handled at Director level in strict confidence and should give full particulars of education, experience and salary required. Box No. W 2341.

TELEPHONE TRANSMISSION ENGINEER, experienced carrier current equipment, filter design and testing, wanted by American manufacturing firm for work in Italy. W 2392

TEST ENGINEER required with experience on test and final adjustment of electrical instruments and good general knowledge of thermionic valve applications. Prospects of advancement to supervisory post for suitably qualified man after period of experience with company's products. London area. State age, full details of training, experience and salary required. Box No. W 2380.

TESTING ASSISTANTS required for High Frequency Cables, with National Certificate or equivalent qualifications. Previous experience not essential. Siemens Brothers & Co. Limited, Ref. 423, Woolwich, London, S.E.18. W 2376

THE GENERAL ELECTRIC CO. LTD., Brown's 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-£1,200 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 2254

THE TELEGRAPH CONDENSER CO. LTD., have a vacancy for an engineer with a good Degree and industrial experience in research on dielectrics or the manufacture of electrical condensers. The position is of a senior character and is pensionable. Commencing salary will be in accordance with age, qualifications and experience. Write giving full details to The General Manager, The Telegraph Condenser Co. Ltd., North Acton, London, W.3. W 2340

VACANCIES exist in the Development Laboratories for junior and senior engineers experienced in the design of electronic test equipment including valve voltmeters, C.R.O., oscillators, etc. Applicants will be responsible for the development of research models to the production stage and must have a good fundamental knowledge of electrical theory and practical experience of design. Salary according to qualifications and experience. Please quote reference 2/EN. W 2384

VACANCIES exist for development engineers for work on auto control and servo systems. Applicants should be experienced in low fre-

CLASSIFIED ANNOUNCEMENTS
continued on page 8

SITUATIONS VACANT (Cont'd.)

quency electronic techniques, including the use of magnetic amplifiers. Preference will be given to applicants with previous experience in designing equipment to aviation requirements. Salary according to qualifications and experience. Please quote reference 3/EN. W 2385

WAYNE KERR require several engineers for design and development work on electronic equipment. The development programme is varied and ranges from S band oscillators and Q meters to H.F. Signal Generators, Audio Tone Sources, and precision D.C. measuring equipment. There is a particular need for a senior engineer with a good Degree and a background of practical achievement, who will take a leading part in the laboratory and who will qualify for a salary in the range £900-£1,250. The salaries for the remaining posts are in the range £600-£850 depending on qualifications and experience. Write to The Technical Director, Wayne Kerr Laboratories Ltd., Sycamore Grove, New Malden, Surrey. W 2364

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ELECTRONIC ENGINEER. Fluent German, reasonable French. Age 44. General knowledge of modern practice. Requires progressive well paid position within reach of W. London. Box No. W 1374.

HIGHLY QUALIFIED Engineer, 36, good personality and excellent linguist, widely travelled, offers services as technical liaison officer or representative abroad. Box No. W 1379.

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SCOPHONY Torque Motors, Full details, type Etc. to Box No. W 1386.

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PROTOTYPE AND SMALL quantity production. Due to expansion of premises, a well equipped firm of electronic engineers can offer capacity for the manufacture of prototypes and small production quantities of laboratory and similar type electronic gear. Only first-class work required. Box No. W 1387.

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STUDENT has for disposal the following technical journals in unmarked condition. Eleven vols. "Journal Scientific Instruments" 1941 onwards; two vols. "Journal Applied Physics" 1950/51 (Eleven of the foregoing volumes are bound by the publishers); six vols. "Instrument Practice" (Vol. 1 incomplete), three binding cases for same. Cost £65. Offers please. Seville, Oaklea, Waterfoot, Rossendale, Lancs. W 1381

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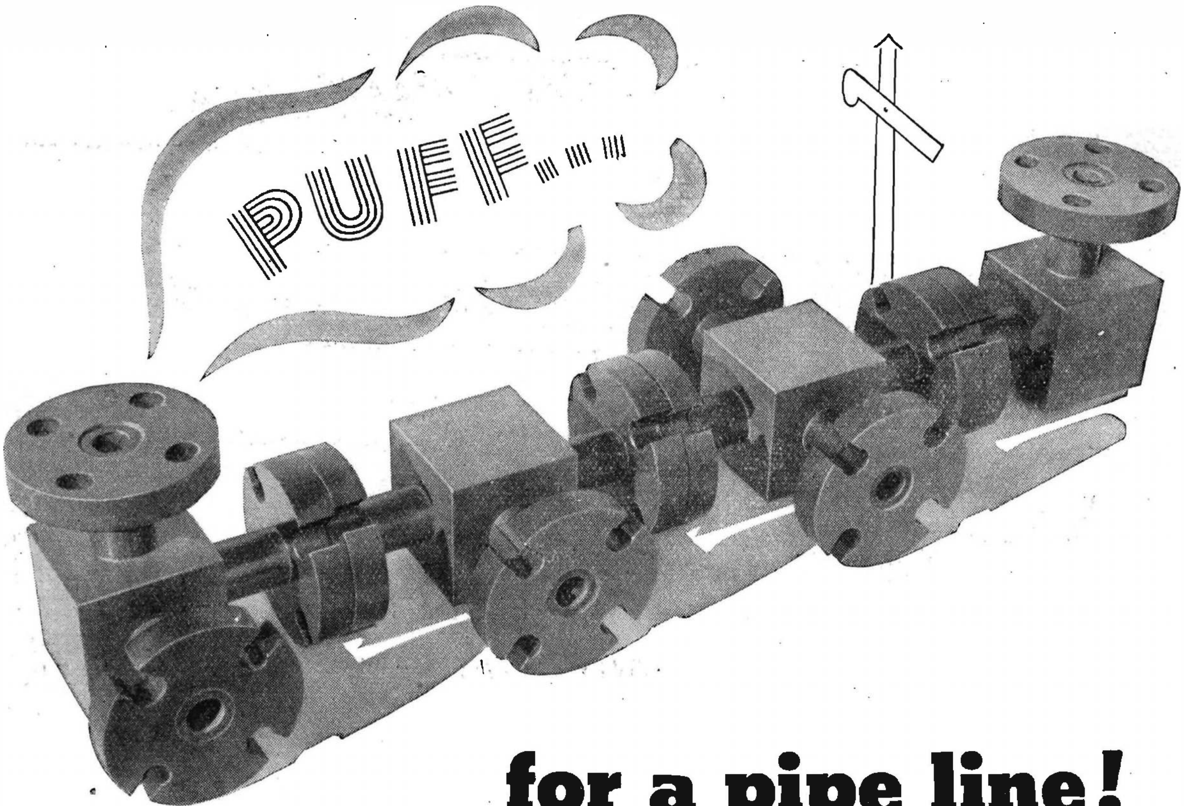
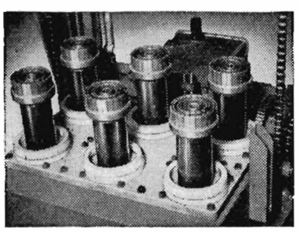
NORTHAMPTON POLYTECHNIC. St. John Street, London, E.C.1. A course of thirteen lectures by a panel of specialists entitled Modern Practice in the Testing and Application of Magnetic Materials will be given on Wednesday evenings at 7 p.m., beginning on 9th January, 1952. Fee for the course 20s. Full particulars are obtainable from the Secretary. W 2339



for a pipe line!

When the engineer first expresses his train of ideas on paper, he is on the right lines if he keeps Tufnol in mind wherever the properties of hardwood or metal do not fill the bill. These Tufnol tubes and couplings, for example, distributing acids, have the tremendous advantage of resisting chemical action. Sleeves and washers on a huge pipe-line in Iraq do their job superlatively because as well as withstanding chemical action, moisture and extremes of climate, they also ensure complete electrical insulation, section by section, vitally necessary in protecting the pipe line against electrolytic effect. But the remarkable qualities of Tufnol do not end here; it is light in weight yet structurally strong enough to mate sympathetically with steel; it will not split or crack under impact; and above all, can be machined accurately and quickly under ordinary workshop conditions! Sheets, tubes, rods, bars, angles, channels are all available; or it can be supplied in specially moulded shapes. Throughout Industry the signal for Tufnol is "Full Speed Ahead"!



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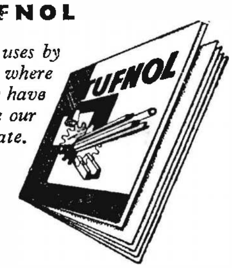

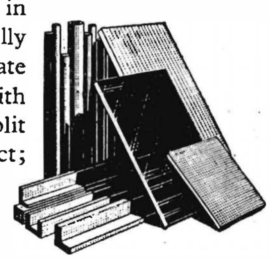

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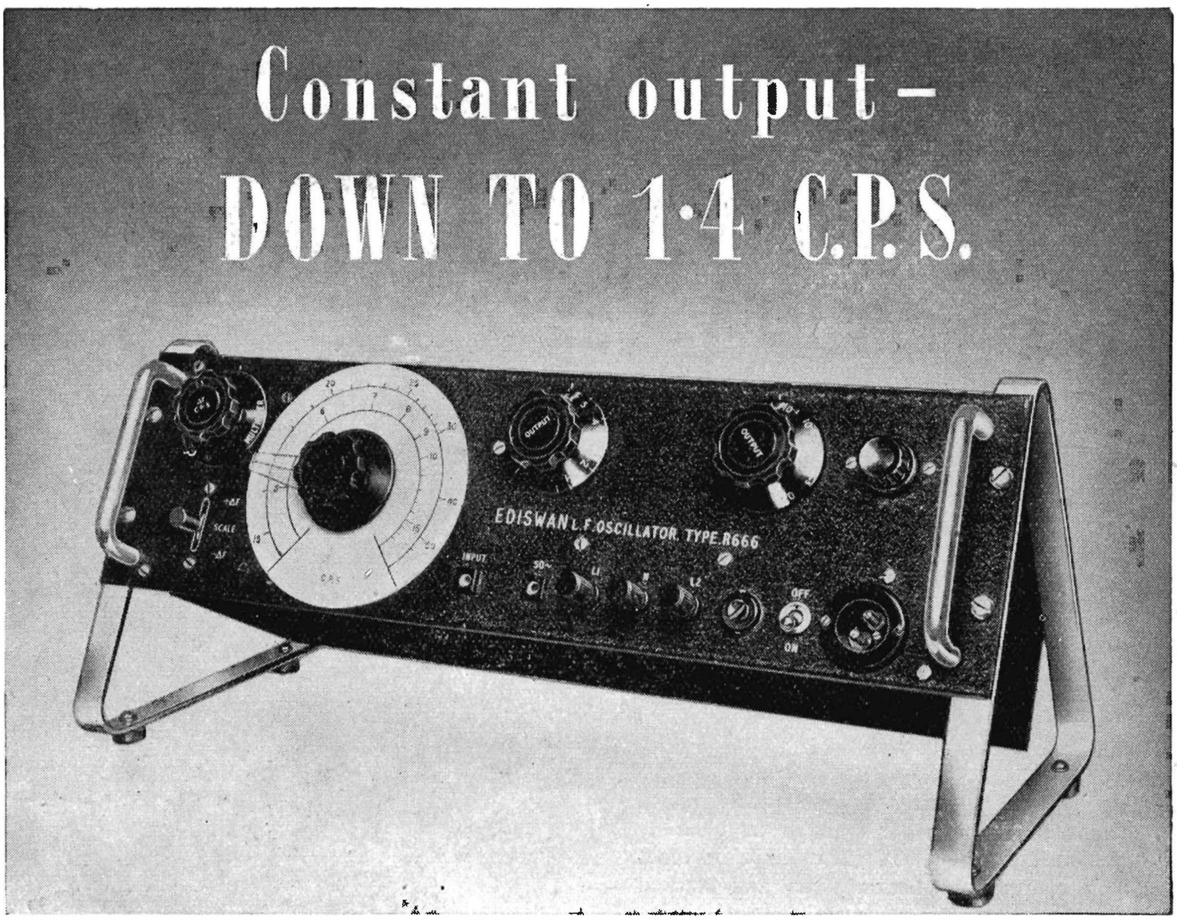

The specially designed resistance capacity circuit of the Ediswan Low Frequency Oscillator type R666 ensures constant output and good waveform even with frequencies as low as 1·4 c.p.s. For testing, calibration, amplifier set-up and in all cases where a dependable low frequency standard is required this instrument is ideal. Supplied in unit form for standard rack mounting. Special stands for bench use (as illustrated) are available.

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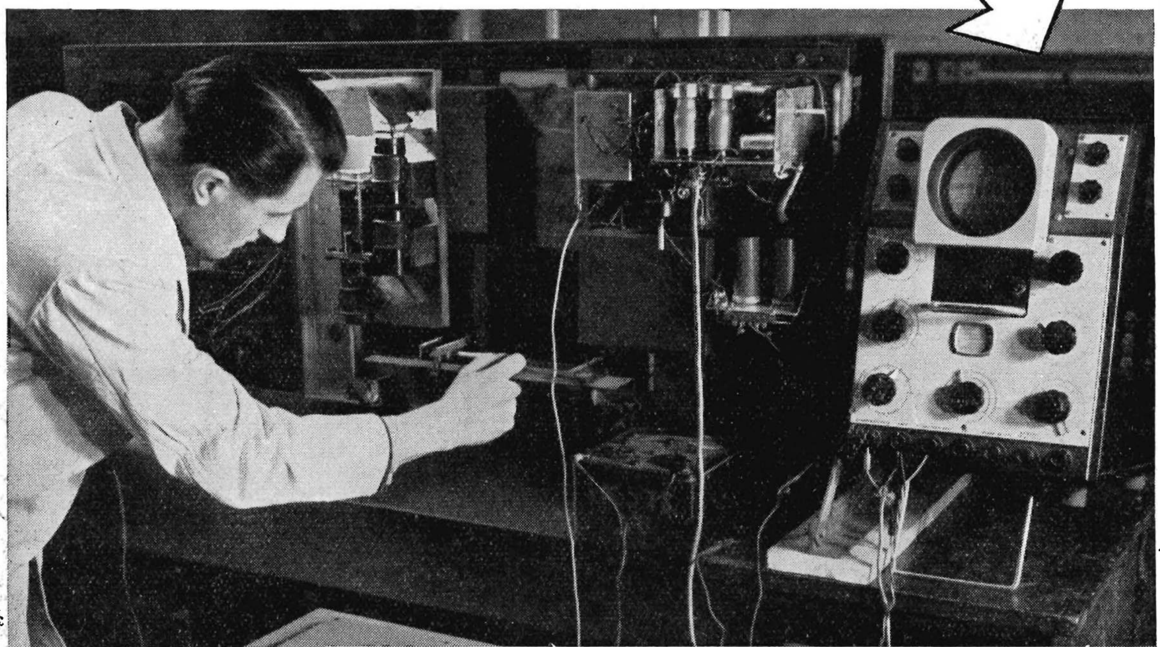

Here, in the Physics Laboratory of a prominent research establishment, is a COSSOR Double Beam Oscillograph in use. Many other industries, ranging from nylon spinning to the manufacture of jet engines, now use this versatile instrument. Typical everyday applications are the tracing of noise, strain and vibration; and the answer to long-standing industrial problems is often provided. Our technical advisory staff will quickly let you know whether the Oscillograph can help with *your* problems.

Here are some details: The Double Beam Tube presents two simultaneous independent traces over the full diameter of a 90 mm. screen, and provision is made for the measurement of both input voltage and time upon the calibrated dials. Permanent photographic records may be made using the Cossor Model 1428 Camera.

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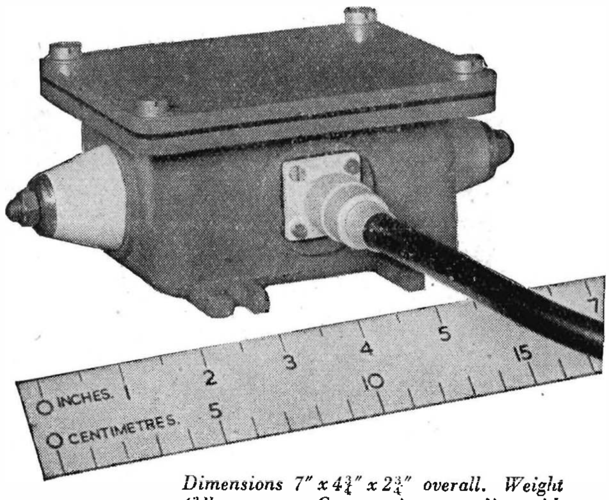
A.T.M.

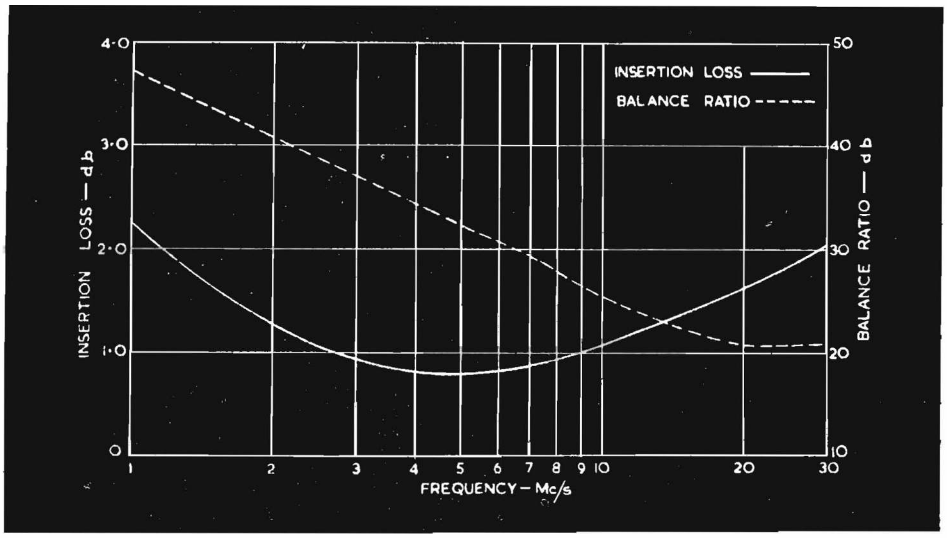
WIDE BAND MATCHING UNIT



Dimensions 7" x 4¾" x 2¾" overall. Weight 4⅜lb. approx. Construction complies with climatic and weather-proof requirements of the relevant Inter-Service specifications.

The "A.T.M." wide band matching unit is designed to meet the need for matching different impedances over an extensive frequency range. The type shown here is for matching a 600-ohm balanced open-wire feeder from a receiving aerial to a 75-ohm unbalanced coaxial cable. Alternative types can be provided for matching other impedance values, either balanced or unbalanced according to individual requirements. The units are compact and light in weight.

Please write for full details.



Characteristics of Wide Band Matching Transformer.
600Ω Balanced: 75Ω Unbalanced. Power rating: 1 watt.

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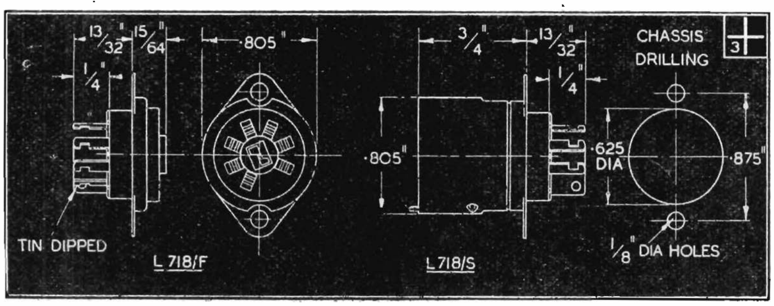
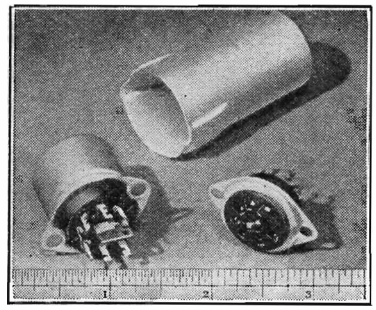
The "Belling-Lee" page for Engineers





B7G VALVEHOLDER

LIST NUMBERS

L 718/F Flange

***Z 560132**

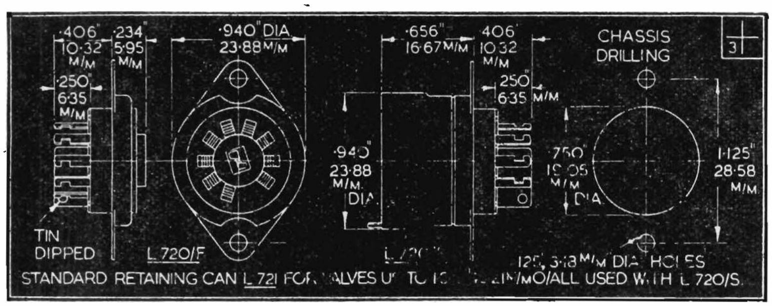
L 718/S Skirt

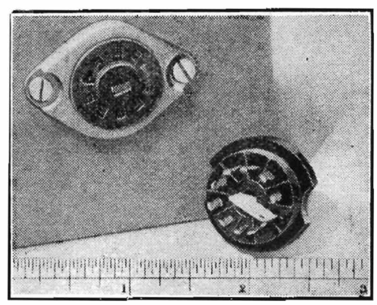
***Z 560127**

L 719 Screening Can

This valveholder complies with R.C.S. 251 and has full Inter-Service* type approval. It is intended to fill the gap between the cheaper types and the very expensive P.T.F.E. holders.

Suitable for most electronic equipment for frequencies up to 200 Mc/s. Low loss nylon filled insulators carry silver-plated beryllium copper contacts differentially hardened to give optimum contact pressure; tags can be bent without damage and are tin dipped. Adequate screening between contacts is provided.





B9A "NOVAL" VALVEHOLDER

LIST NUMBERS

L 720/F Flange

L 720/S Skirt

L 721 Screening Can

The "Belling-Lee" version of this valveholder is now in its initial production stage and samples are awaiting the approval of the appropriate authority.

It is very similar to the B7G and can be supplied either with fixing flange, with a skirt, or with a skirt and screening can.

Limited quantities are now available from stock.

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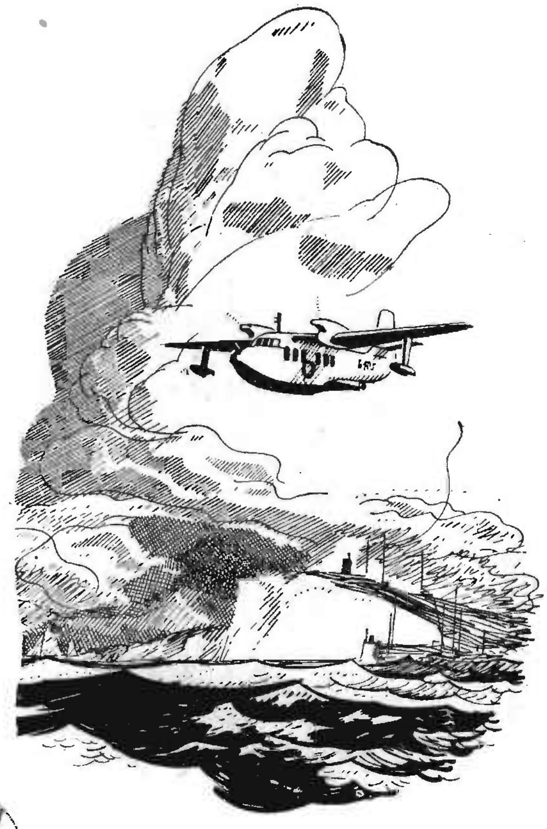

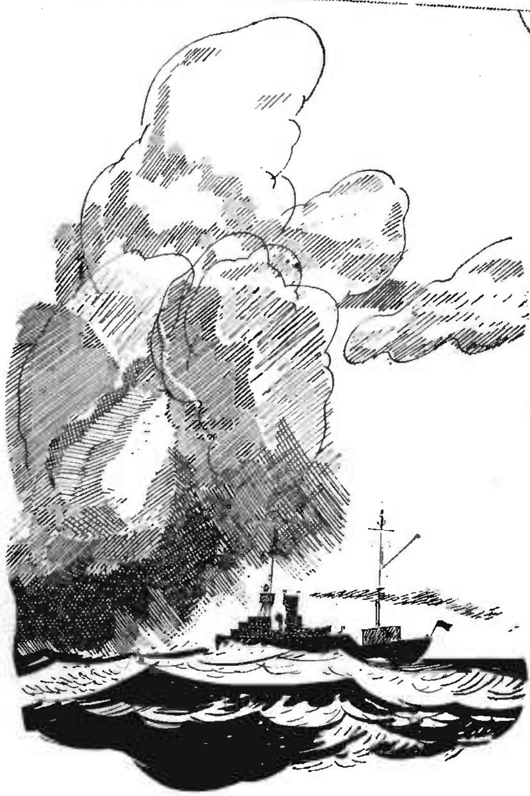

When Marconi died, one tribute said of him " What other men had been content to prove impossible, he accomplished ". From simple beginnings his inventions in wireless have been extended to hundreds of activities. Every weather-ship report, every wireless-bearing taken from a flying-boat and every radio programme broadcast traces back to the pioneer who put his genius at the service of mankind.

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD · CHELMSFORD · ESSEX

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An Announcement . . .

DUREX ABRASIVES LTD. wish to announce that as from June 14th, 1951, the name of the Company has been changed and is now the MINNESOTA MINING & MANUFACTURING COMPANY LTD. Identification will be as before, except that the words "Scotch Boy" will be used instead of "DUREX" as a prefix to the name of the material, e.g., "Scotch Boy" Magnetic Recording Tape instead of "Durex" Magnetic Recording Tape.

Existing high standards in the quality of the products will be maintained, the change is in name only.

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Magnetic Recording TAPE

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Electronic Engineering

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

Vol. XXIV JANUARY 1952 No. 287

Contents

Published Monthly on the last Friday of the preceding month at 28 Essex Street, Strand, London, W.C.2.

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Electronic Engineering

Vol. XXIV. JANUARY 1952 No. 287.

Commentary

AN important anniversary occurred last month which, although marked by appropriate references in the scientific press, received very little attention from the general public.

It was, of course the fiftieth anniversary of the first transmission of radio waves across the Atlantic on December 12th, 1901, by Marconi and his team of experimenters. Some technical details of these successful experiments and the almost overwhelming difficulties involved were included in our last month's issue, but we hope we may be excused if, before looking forward into 1952, we pause to see how far we have come since that grey winter day just fifty years ago.

The achievement created a tremendous sensation throughout the civilized world at the time and in a remarkable leader of the day *The Times* prophetically referred to it as "an event, the importance of which it is impossible to overvalue." Other equally sensational results followed in quick succession and the adoption of this scientific novelty as a means of communication brought some astonishing results. What wonder there was for example in the dramatic wireless messages from the sinking "Titanic".

Some of the apparatus used at the time is now housed in the Science Museum, but the station at Poldhu from which these transmissions took place is now no more. In 1902 a regular trans-Altantic wireless telegraph service was inaugurated at Poldhu which remained in operation until 1922.

Thereafter it was used by C. S. Franklin for his work on short-wave directive arrays until the station was finally demolished in 1933.

Today only a granite column marks the site of these historic achievements, with a summary of the events on three of its four commemorative plaques. On the fourth plaque is the statement "The site of this column and some six acres of land on the edge of these cliffs together with the cliffs and foreshore beneath them were given to the National Trust in 1937 by the Marconi Company to commemorate the pioneer work done at the Poldhu wireless station between 1900 and 1933 by its research experts and radio engineers."

From these early beginnings have sprung the complex network of radio communications, broadcasting, television and the like, which have developed during the first fifty years of its history. At the turn of the half century it is difficult to recall all the milestones passed on this exciting journey, but it should be pointed out that the journey did not begin with the advent of broadcasting in the 1920's.

It is very much more difficult as we continue our forward journey to predict what lies ahead, for what has already passed before us has exceeded the wildest forecasts made in 1901. If the first fifty years can be regarded as the wireless age, what we are now entering into will be without doubt the all-electronic era, the outlines of which we can only dimly perceive at present.

* * *

The impact of television on our way of life and the destruction which it threatens to the gentler arts and intellectual pursuits is a subject which has given rise to considerable comment on both sides of the Atlantic since the war.

Many of the arguments put forward have, we feel, been used before. A hundred years ago the invention of photography aroused similar forebodings in the minds of our Victorian ancestors and we would like to quote without further comment extracts from a letter published in 1851 by a prominent newspaper. "Sir,—I beg to bring to your notice the serious harm likely to come from the increasing popularity of photography. Since Mr. Talbot and M. Daguerre perfected their processes for fixing a living image on paper a few years ago there has been an alarming increase in the popularity of this unnatural pastime.

"Already, I am informed the fascinations of the photograph album have had their effect on the thousands of children who would be better employed in pit or mill; already the reputations of Landseer, Turner, and even of Martin and Westall are believed to be suffering; and I can myself vouch unhappily from my own family circle that idleness and vanity are encouraged by the constant posing for portraits, and the subsequent poring over them in unhealthy crouching attitudes."

* * *

While we are on the subject of anniversaries we should not allow the occasion to pass without offering our hearty congratulations to our sister journal *The Engineer* on the publication of its 5,000th issue last month.

The Engineer published its first issue, consisting of twelve pages, on January 4, 1856, and its original aim "to keep pace with the progress of all those departments of the arts and manufactures which contribute to our material comforts and to represent effectually the industrial activity in which we live" has, may we be allowed to say, been more than adequately fulfilled.

Ever since, it has appeared regularly week by week with only four exceptions, and it is now within easy reach of its first centenary—a remarkable record of which any journal might be proud.

The Activities and Equipment of an Industrial Electronics Laboratory

(Part 1)

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

This series of articles is of the "integrating" type: i.e., no claim is made to present material not previously published, but the author has endeavoured to give a constructive review of the whole subject.

MANY articles have appeared in the technical press describing the design and applications of particular electronic instruments for use in industrial measurement and control; but with one or two notable exceptions very little has been written from the viewpoint of the user in the industrial research laboratory. It is the purpose of this article to repair this deficiency by pointing to the specific needs of the industrial research worker—particularly in the heavy engineering industry.

In Part 1 the writer proposes to show the very considerable progress which has been made in the application of electronic techniques to the problems of measurement—as well as of automatic control—in the engineering industry; yet at the same time to indicate the wide field which still exists for their further development. Examples will, in the main, be selected from the work of one particular research and development laboratory. In subsequent parts of the article the circuits of electronic measuring equipments will be considered, together with the very important subject of the detector devices or "transvertors" which, in general, make electronic measurements possible. As an underlying theme it is intended to show how, by enlightened planning on the basis of standardized "unit" instruments, the whole of the extremely wide and still expanding field of investigations made possible by present-day electronic techniques, can be brought within the scope of laboratories of even quite moderate means.

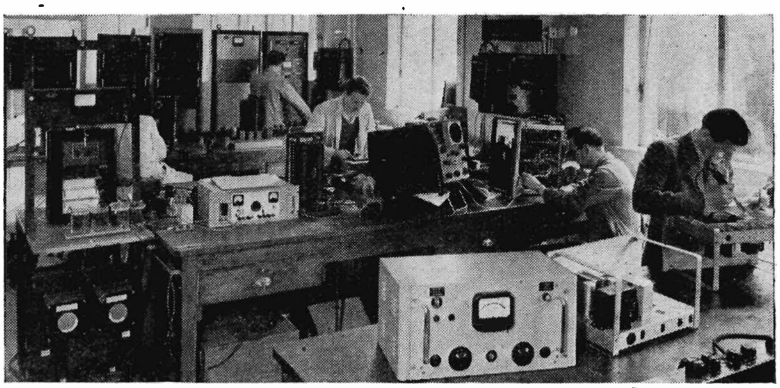


Fig. 1. General view of part of an Industrial Electronics Laboratory

Electronics today has become a part of every branch of scientific activity from medicine to meteorology, so that its invasion into industry, and especially into industrial research, may be taken as a matter of course. It is perhaps especially at home in electrical engineering (with which branch the writer is principally concerned), but practically every other major industry—chemicals, steel, automobiles, ship-building, textiles and of course the aircraft industry, now has its own electronics laboratories. This offensive of electronics on the industrial front, it may be said here, comprises two main spearheads—one in the field of measurement, the other in that of automatic control. The present article, however, will deal primarily with the former aspect, and but passing reference can be made to electronic control devices. Incidentally (to continue the previous metaphor), while the Research Department has its "H.Q." in the laboratory, many "sorties" must be made into the factory—and often outside—so that its weapons must be as mobile as possible. Light portable instruments and readily transportable test racks capable of withstanding rough usage are consequently very necessary: of this, more will be said anon.

To review all of the possible applications of electronics, even in the field of measurement alone, would provide material for a large volume. Hence it must suffice to indicate briefly the general fields of investigation to which electronic methods have mainly been applied—more especially in the electrical industry.

Testing Materials

The testing of materials probably constitutes the most important single class of electronic measurements — if indeed this can be regarded as a single group. Thus X-rays and the electron diffraction camera are both already well established techniques in the field of metallurgy, while the electron microscope, a closely related device of more recent development, is finding a rapidly increasing number of applications in many fields of research. Metallurgists are at present increasingly turning their attention to the development of special alloys to withstand high working temperatures, for such applications as the aircraft jet engine and the industrial gas turbine. In this sphere the electronic engineer can assist by providing equipment for accurate temperature measurements and also for the precise control of furnace temperatures. Creep testing, in particular, which has recently received a considerable impetus in many laboratories, calls for large numbers of electronic furnace controllers, the requirements of which are very rigorous: temperatures must be maintained within 2° C. at values up to 1,000° C., and tests may run without interruption (which would involve great inconvenience and expense) for many months or even years. A new electronic controller has recently been developed in the writer's laboratory to meet this need, in which all switching devices

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

or other moving parts have been eliminated from the control circuit.

Magnetic testing methods, apart from their direct and obvious application to determining the properties of magnetic (and non-magnetic) steels for the electrical industry, find application in the magnetic sorting bridge, described elsewhere,[1] used for checking such factors as hardness, heat treatment, alloy composition, etc., of ferrous metal samples, by comparison with a standard specimen. This instrument, which in its original form as the Hughes

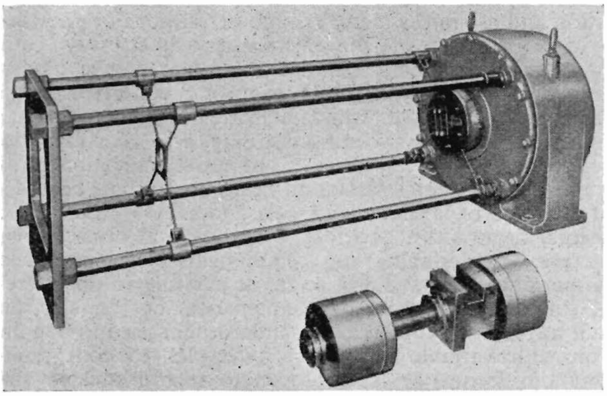


Fig. 2. Large 5kW moving-coil vibrator for fatigue tests at up to 2,000c/s In foreground: tunable mechanical resonator

Magnetic Balance dates back to 1897, comprises two identical air-cored solenoids connected in an A.C. bridge circuit. The standard specimen and the test sample, of nominally identical dimensions, are placed centrally in the two solenoids, when any difference between the *B-H* loops of the two materials, giving rise to differences in the induced voltage waveforms, produces a characteristic diagram on a cathode-ray tube capable of interpretation, with experience, to show up slight variations in any of the properties referred to above. A sinusoidal A.C. time sweep, of the same frequency as the voltage across the coils, is generally used.

Applied to the testing of finished component parts, the magnetic sorting bridge, and also the high-frequency eddy current crack detector,[2] and "magnetic ink test" may all be used for detecting minute or hidden flaws, while the more recently developed supersonic flaw detecting technique[3] provides an even more powerful tool for locating defects in the interior of large metal castings and forgings.

Engineering Applications

In the general engineering field, the measurement and analysis of vibrations in structures and machinery of all kinds, as well as of the noise to which they give rise, are important every-day problems for which electronic measuring instruments are essential. Stress and strain measurements,[4,5] and in fact all of the established methods of mechanical testing of materials, are now carried out with greater facility with the aid of electronic equipment: the wire resistance strain gauge, on which a mass of information has been published during the last few years,[6] has revolutionized researches in this field. Nevertheless there is much misconception as to the capabilities of this technique. The strain gauge, unless used with very great care, is a device of low inherent accuracy and success in its use depends largely on the appreciation of its limitations—particularly when used under adverse circumstances (such as under water) or at very low loadings. On the other hand, with the aid of electronic amplifiers, it does make possible the study of very rapid transient as well as static strains. Furthermore, recent advances in the art have made possible the application of strain gauges on high speed rotating bodies and also on surfaces at temperatures up to about 700°C.

In the closely related province of vibration fatigue testing—as well as for determining the natural frequencies of machine parts—electrical or electronic methods are predominant both for applying alternating stress cycles (Fig. 2) and for the measurement of strain, elastic modulus and specific damping capacity.[7,8] Vibration problems may in general be attacked in two ways—by removing the cause and by restricting its effects. In the first class may be cited the case of two large forge hammers located close to delicate precision machinery, in which resilient mounting of the former was shown to reduce to negligible amplitude the shock-waves transmitted through the ground.[9] Among problems in the latter category which the writer has investigated was that of a brickwork annealing oven which vibrated at dangerous amplitude owing to the chance resonance of its structure with a distant low-speed compressor. In another instance, again, the resilient mounting of creep testing machines on heavy rubber mounted concrete foundation blocks was resorted to in order to eliminate the effects of unavoidable ground vibrations from a main railway line. Fig. 3 shows a laboratory test rig used for determining the dynamic elastic properties of samples of rubber for such applications.

One of the problems confronting the electronic engineer responsible for maintaining measuring equipment for mechanical testing is that of calibrating vibration meters and pick-ups. Fig. 4 shows a vibration test bed installed to meet this particular need: it comprises a heavy steel vibrating cantilever, tunable over a wide range of resonant frequency by means of adjustable clamps, and excited by a 100 watt moving coil vibrator. Absolute measurement of vibration amplitudes is carried out by a photoelectric method, which will be described later, using a pair of 100 lines/inch gratings—a standard which the non-electrical engineer will have no reasons to doubt. In addition to serving for the calibration of existing vibration meters, this equipment has been used in developing several new vibration measuring devices both for experimental purposes and for use in permanent vibration recorders.

Among other examples of electronic techniques now

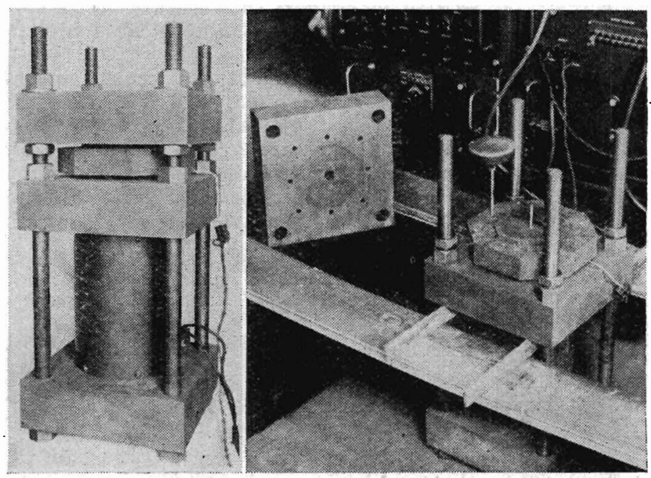


Fig. 3. Test rig for determining the elastic properties of rubber

at the disposal of the mechanical engineer may be cited the electrical torque meter (various types of which are in use); the electronic tachometer for accurate speed measurement; high speed photography and stroboscopic study of machinery in motion; the cathode-ray engine indicator[10,11] and the explosion pressure recorder—the latter employed possibly in conjunction with photographic observation using micro-second flash tubes.[12] The measurement of surface temperatures in inaccessible positions—

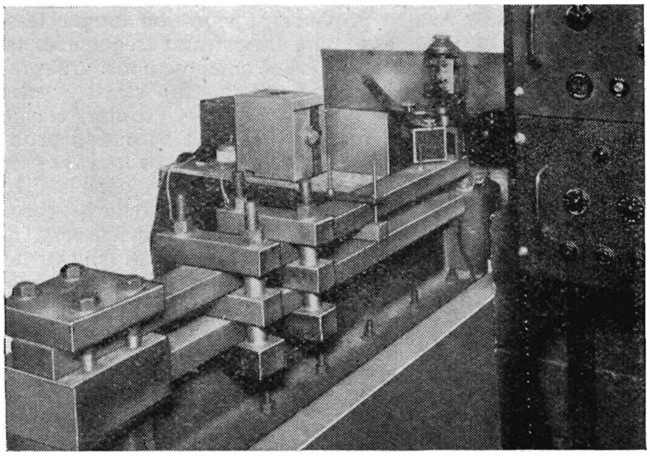


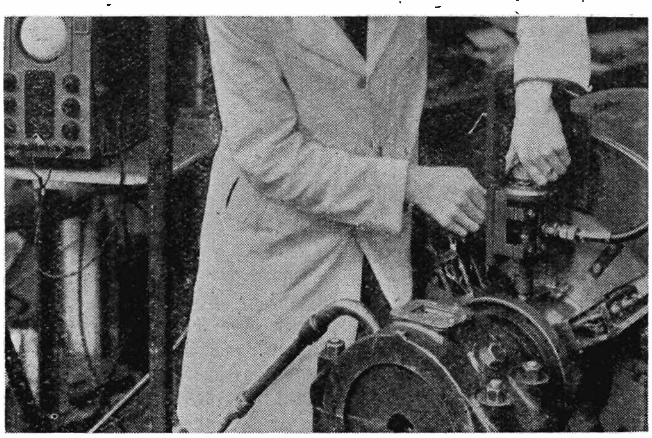
Fig. 4. Test bed for the calibration of vibration measuring equipments

particularly on moving parts—is now possible, within the working range of engineering materials, by radiation pyrometry,[13] owing to the introduction of new types of sensitive photo-conductive cells.[14]

The electrical capacitance strain indicator is another equipment of considerable general utility in this field. It has been used, for example, for measuring the expansion and distortion under centrifugal forces of large high speed rotating parts; for picking up the vibrations of electrically excited test specimens (and hence providing a signal for a self-maintained vibration system); for measuring static bending strains in a 40 ton alternator rotor under its own weight; for checking the contour of large motor commutators running at speed; and for many similar purposes. Fig. 5 illustrates the last mentioned application. In nearly all of these instances the ability of this equipment to measure displacements without actual mechanical contact is a considerable asset, while the fact that it can be designed to give static response greatly facilitates the problems of calibration, in addition, of course, to permitting static measurements. Fig. 6 shows a typical pair of electrodes with micrometer screw adjustment for calibrating.

Besides its many uses for strain and displacement indication, the electronic equipment employed with capacitance type gauges may also be used for a variety of other measurements. Very satisfactory capacitance type pressure pick-ups[15] (used in certain types of engine indicator and for many other purposes), vibration and acceleration pick-ups, and also capacitance torsiographs for aircraft engine testing[16,17] have been designed and used to good purpose.

Fig. 5. Checking a large motor commutator for irregularities of contour



Industrial Type Equipment

The work of the industrial electronics research laboratory, it may be said here, includes the maintenance, and when necessary the design and manufacture, of equipment for all of the diverse applications indicated in the foregoing paragraphs, as well as, for the most part, their actual use during experimental investigations and tests. Practically all of the equipments referred to so far have been devices for experimental measurements. In addition, however, the production of special indicating or control devices is frequently required for permanent installation and use in the factory, in power stations or elsewhere.

In a number of power stations supervisory equipments are now being installed in order to give a closer insight into the mechanical operating conditions in the generator turbines, in which high steam temperatures and intermittent running conditions may give rise to serious distortions of moving parts. Continuous indication can be given by these equipments, on multi-point chart recorders, of thermal expansions and clearances at various critical points, steam valve positions, vibration and other relevant factors. In designing these equipments electronic devices proper have been avoided, so far as possible, in the interests of simplicity and ease of maintenance, but an electronic unit at present adopted as a standard item used in conjunction with variable inductance type pick-up coils excited at audio frequency is employed to record turbine shaft eccentricity (caused by uneven cooling). Steady indications

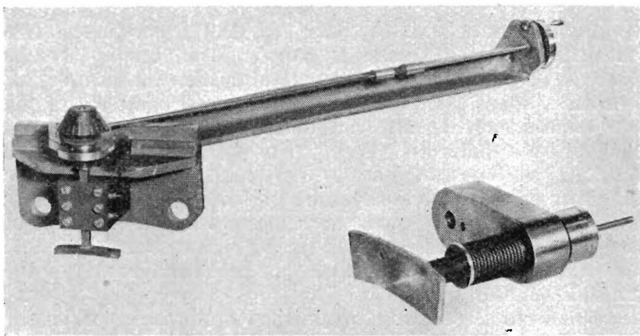


Fig. 6. Typical capacitance pick-up electrodes with micrometer adjustment for static adjustment

are obtained with uniform response over the whole shaft speed range from $\frac{1}{3}$rev/sec to normal speed.

Fig. 7 shows an equipment of the "supervisory" class permanently installed in the factory, as an aid to the dynamic balancing, at full speed, of the largest turbo-alternator rotors. It is a multi purpose instrument giving meter indication of speed and of vibration amplitude (a warning device is incorporated in case of serious unbalance), while the cathode-ray tube gives phase and amplitude indication from which the magnitude and position of the required balancing weights can be deduced. The protective water-tight casing of this equipment—completely enclosing it when not in use—is particularly to be noted.

The laboratory with which the writer is associated has in recent years designed a considerable number of electronic equipments on a "production" basis, of which the supervisory equipments just described are but one instance. Generally these are supplied as auxiliaries to other machinery or equipments produced by the firm. Reference will be made later to other equipments in this category.

It may be appropriate at this point to remark that, despite the very considerable inroads already made by electronics into the engineering field, there is still a good deal of prejudice among engineers against employing electronic apparatus containing what are still regarded as potentially unreliable devices—thermionic valves—anywhere in conjunction with their plant. This has, of course, greater significance in relation to automatic control than to measuring equipment for experimental use; but nevertheless, inasmuch as test runs on large machines or industrial plants are always expensive and may entail holding vital plant out of commission at considerable inconvenience, the risk of wasting a test through faulty experimental equipment simply cannot be afforded. Unless therefore electronic methods are to be allowed to fall into disrepute, too much stress cannot be laid on the importance of rugged construction, on careful design, and on liberal

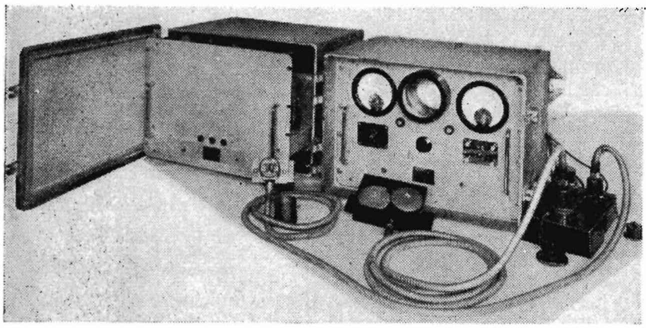


Fig. 7. Electronic supervisory equipment for balancing of large rotors

rating of components, in all equipment intended for this class of work. In the same vein, a warning might perhaps be given against allowing over-enthusiasm on the part of the electronic engineer to lead to the adoption of an electronic method where a simpler, and therefore probably more reliable, non-electronic one will serve.

Electrical Engineering

Touching now on purely "electrical" measurements, which are mainly considered outside the scope of this article, the cathode-ray tube has, of course, found extensive application for many years, in the electrical manufacturing and supply industries, for investigating surge voltages in equipment and on power transmission and distribution systems, caused by switching, by mercury arc rectifiers and arc furnaces (a prolific source of high voltage disturbances) and, of still greater importance, by natural lightning on overhead power lines. In high voltage impulse testing—used to simulate the effects of lightning surges on transformers, alternators and other power equipment—the cathode-ray tube is used for control of the test voltage wave shape, for the detection of breakdown in the plant under test,[18] and also for observing the behaviour of surge voltages in windings.[19] In this connexion it is of interest to note that the very great improvements made during recent years in sealed glass cathode-ray tubes for high speed recording, by ordinary external photography,[20,21] is now making it possible for this type of oscillograph to supersede the extra-high-voltage continuously evacuated oscillograph. Hitherto, this latter type, in which the photographic film or plate is exposed *inside* the vacuum (where it is inserted through a vacuum-tight cover), together with its associated pumps, E.H.T. supplies and other auxiliaries, has been regarded as an essential item in the impulse testing laboratory and the substitution brings material advantages in convenience, reduced maintenance and time saved in testing. The success achieved in this new line of development will be indicated by the fact that a present-day 10kV tube will satisfactorily record, with an external camera, a single trace exposure of a 100Mc/s wave.[20]

In the same field, the "recurrent surge oscillograph,"[19] employing ordinary low voltage cathode-ray tubes, affords an extremely valuable tool for the evaluation of impulse voltage stresses occurring in electrical plant—which have not so far proved amenable to exact calculation—and also, in slightly modified form for determining "restriking voltage" conditions at switching points in electrical power systems.

Physical and Chemical Research

Turning now from engineering to other branches of research, electronics has, as is well known, found very extensive application in physics—particularly in the recently developed branch of "nucleonics": so much so, in fact, that this whole field must necessarily be considered outside the scope of the present series of articles. In chemical research, and the chemical industry generally, electro-chemical methods of analysis are widely used for a variety of purposes: *p*H measurements are used to give exact indication of acidity of solutions—and hence as a precise indicator in titrations; conductivity measurements of electrolytes provide a convenient means of controlling the concentration of solutions in chemical plants; the polarigraph, in which recordings are made of electrolytic currents flowing in a test cell with gradually increasing applied D.C. potential affords yet another method of identifying and estimating constituents present in weak solutions.[22a]

A different technique in this general category which has recently become of considerable importance is that employed in the infra-red spectrometer for the analysis of both liquids and gases. Present-day knowledge of molecular structures—which may be regarded as dynamic systems comprising atomic masses bound together by precisely determined elastic constraints—shows that each molecule has a number of definite and theoretically definable vibration modes and resonant frequencies. These frequencies correspond to the wavelengths of the absorption bands of the substance—principally in the infra-red spectrum. Absorption spectrograms (Fig. 8(b)) for unknown organic substances or mixtures thus provide a

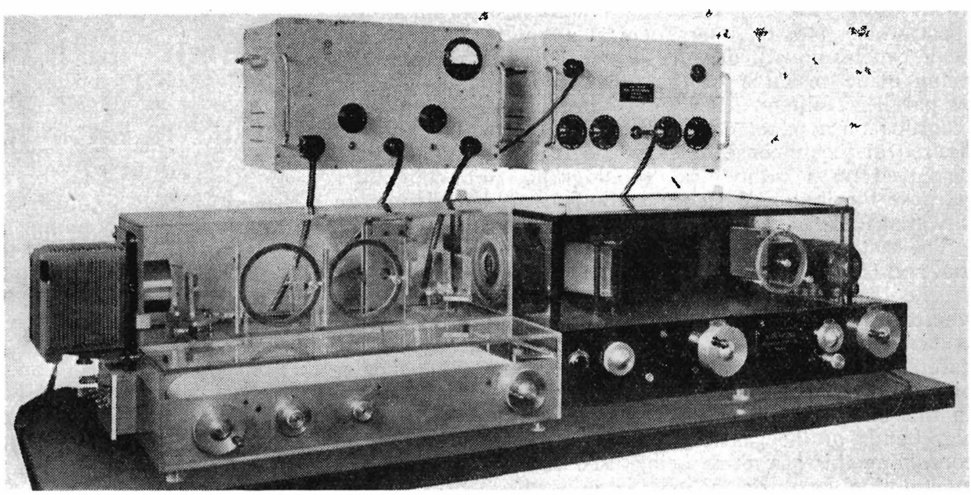


Fig. 8(a). A double beam infra-red spectrometer with amplifier and recorder

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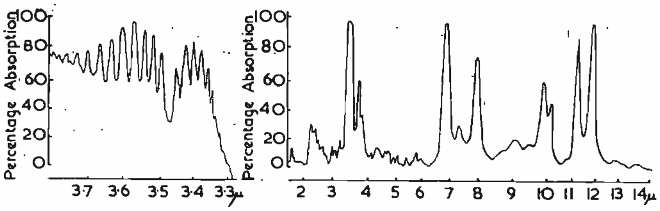
very sensitive means of identification of the constituents, while study of the spectra of known substances affords in turn further information on the structure of molecules. It is in fact found, using modern high grade spectrometers, that the individual spectral lines themselves, in the case of gases having simple molecular structures, have a "fine structure" with a number of "sidebands," associated with rotational vibrations of the individual molecules, somewhat analogous to the sidebands of a radio carrier in sound broadcasting.

Fig. 8(a) shows a recent infra-red spectrometer with its associated electronic amplifying equipment, while at (b) typical spectrograms are given, as reproduced on the recorder built into this instrument. In principle, radiation emitted by a Nernst filament (maintained at very constant temperature) is transmitted through the sample under test and then through an optical system incorporating a slowly rotated mirror and a rock salt prism, in order to



Vibration-Rotation Spectrum for Hydrochloric Acid Gas

Absorption Spectrum for 0·1mm of Cyclohexane (Recording time 20 minutes)

Fig. 8(b). Typical infra-red spectrograms

sweep through the infra-red spectrum. The resulting radiation beam, of varying intensity, is ultimately focused on to a bolometer (a small, temperature sensitive device with low noise level and thermal capacity) the resistance of which changes according to the energy falling upon it. A signal is obtained which requires amplification some 100 million times in order to operate the recording equipment. In order to overcome the obvious problem of low signal-to-noise ratio with a voltage gain of this order, recourse is made to selective amplification with a bandwidth of about 1c/s. For this purpose the radiation beam in the spectrometer is itself interrupted at about 16c/s by means of a synchronously driven shutter device, the amplifier being made selective to the same frequency by the use of parallel-T filters. The final amplified output may be recorded on a paper chart, or (where speed of analysis is desired at the expense of some degree of detail) may be displayed on a cathode-ray oscillograph. For the latter purpose the long persistence cathode-ray tube screens are advantageous.

The instrument just described is essentially a laboratory tool and is, of course, unsuitable for giving direct indication of the composition of gases in chemical plants or elsewhere. The same physical principle has however been utilized in a gas analyser developed independently on different lines in America and in Germany at the beginning of the war, and now being made in this country. In this device total absorption in all of the characteristic wavebands of the gas to be estimated is measured, a cell containing this gas alone being used as the detector. The interruption principle is again employed—at a frequency of about 6c/s. The test is a comparative one; i.e., the unknown sample under test is compared with a "blank" cell. Difference in energies received by the two corresponding detector cells results in differential pressure variations (at the interrupter frequency) which are detected by means of a membrane type capacitance detector element placed between the two cells. An electronic circuit indicates continuously the amplitude of the small 6c/s capacitance variations on an indicating meter, calibrated directly in percentage of the gas being measured. Sensitivity is such that 0.01 per cent of CO_2, for example, will give full scale deflexion.

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Note.—*It is obviously not possible to give a comprehensive bibliography of so wide a subject, but so far as possible the writer has endeavoured to select the most useful reference(s) on each subject, from the bibliographies of which the reader will, in general, be guided to further publications.*

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(To be continued)

Radio Direction Finding

Radio Research Special Report No. 21.

During the war much progress was made in Germany in radio direction finding. For example, there were devised some novel arrangements to improve the accuracy of both direction and position finding. Radio Research Special Report No. 21, published recently, contains translations of nine papers written by German technical experts in this field of radio. Seven of the papers were presented originally at an official German conference on navigational aids and allied problems held at Landsberg in 1944 and two are later contributions. The Report should be of considerable interest to contemporary scientific and technical workers on this subject.

Some of the papers contain the results of fundamental investigations designed to demonstrate the limitations in the accuracy of finding a position or direction imposed by wave propagation and other conditions. The relative merits of determining direction by the measurement of phase difference and time of arrival of the various component waves are discussed. Other papers describe the principles and experience obtained with new techniques demonstrating the influence of aerial spacing, a topic which has now become familiar to all those concerned with recent developments in the subject of radio direction finding.

The papers are published under the name of the original author and the translations were provided by the Admiralty.

Equipment for Acoustic Measurements

(Part 5)

A Portable $7\frac{1}{2}$ Watt Loudspeaker Amplifier

By D. E. L. Shorter,* B.Sc., A.M.I.E.E. and W. Wharton,* A.M.I.E.E.

Previous articles in this series have been concerned with equipment for generating tone pulses and other signals used in acoustic measurements. To complete the series, the present article describes the power amplifier used to drive the loudspeaker in the studio under test.

IN the testing of studios and auditoria, special attention is paid to long decay phenomena which occur when the reverberant sound has fallen 20db or more below the level of the direct sound from which it originated. To obtain an adequate signal-to-noise ratio, therefore, the initial sound level produced in the studio should be as high as possible. The maximum amplifier power which it is practicable to employ for this purpose is about 10 watts, since most loudspeakers will not handle more without damage or excessive distortion at low frequencies. The power amplifier designed for the portable acoustic test equipment gives $7\frac{1}{2}$ watts undistorted output, the exact figure fixed by the rating of the output valve and transformer.

The Circuit

The circuit is shown in Fig. 1. T_1 is a magnetically screened input transformer designed for connexion to any source not exceeding 600 ohms in impedance. The primary impedance is 10,000 ohms and the amplifier may therefore be connected across a line for monitoring purposes without seriously affecting the signal level.

The first stage of the amplifier consists of a pair of CV138 valves, V_1 and V_2, paraphased by a common cathode resistor R_{10}. Negative feedback from a tertiary winding on the output transformer T_2 is injected between the low-potential end of R_{10} and earth. The circuit is similar to that of the small output stage described in Part 1 of this series. In the present application, however, the valves are used as voltage amplifiers with relatively high anode resistors, and low feeds (about 1mA); and the mutual conductance is necessarily lower. This reduction of mutual conductance increases the degree of unbalance between the anode currents from about 6 per cent to about 20 per cent, but the values of the anode resistors R_5 and R_{11} are so chosen that equal signal voltages appear on the two grids of the push-pull output valve V_3.

Since the grid of V_1 is necessarily raised above earth potential by the voltage drop across R_{10} and R_{24}, a blocking capacitor C_1 is necessary between this grid and the slider of the gain control potentiometer R_1. The capacitor C_1 and the grid leak R_3 are included in the negative feedback loop and the time constant C_1R_3 is therefore made very long to minimize the phase shift introduced at low frequencies.

Choice of Output Valve

For a power amplifier intended to work in a confined space, it is preferable that the output valve should operate under class AB conditions to reduce the power dissipated at the anode. The temperature rise of the enclosure is thus kept as low as possible and a valve having a smaller envelope could be used. Most of the output pentodes available when this amplifier was designed were rated for the full anode dissipation involved in class A operation, and were unnecessarily bulky for the present purpose. A small transmitting valve type QQV/04/20, having two tetrodes in a common envelope and rated for a dissipation of 10 watts per anode, was therefore used as a push-pull pair.

The maximum screen voltage for the QQV/04/20 is 225V, but to allow for the regulation of the H.T. supply, the design was based on a figure of 200V on the screen with the amplifier delivering its maximum power output. With the maximum permissible anode voltage of 400V, the valve will then give 19 watts before waveform clipping begins, while with 200V on both screen and anode, 8.5 watts can be obtained. The latter figure happens to be the maximum power which can be handled by an output transformer on a standard 101 T core (I.S.C.C. lamination No. 401A). Deduction of the transformer losses leaves an output of 7.5 watts available for the external load, and this figure was considered adequate for the purpose in hand. The valve is accordingly operated with equal supply voltages on both screen and anode, with a consequent simplification of the circuit.

Output Transformer

Reference has already been made to the core of the output transformer. As the output stage is operated under class AB conditions, special care is taken in designing the windings to ensure tight coupling between the two halves of the primary. To this end, each half of the primary winding is divided into three cross-connected sections placed on either side of a centre partition on the spool. Such an arrangement of sections necessarily increases the capacitances from one part of the winding to another and to earth, so that at frequencies above 10kc/s the signal voltage is unevenly distributed. To maintain the correct phase relationship between the voltages of the primary and tertiary windings irrespective of the load connected to the secondary, the tertiary is split into eight parts appropriately distributed.†

The core laminations are interleaved in groups of four to reduce polarization arising from any unbalance in the feeds of the output valves. In addition, the feedback system is so designed that a reduction in the inductance of the output transformer does not produce instability.

The secondary winding of the output transformer is split into two sections connected in series or parallel for loads of 12 ohms or 3 ohms respectively.

Feedback Stability

The constants of the amplifier were adjusted for stability under all conditions of load by reference to the gain/frequency characteristics of the feedback loop over the range 2c/s to 500 kc/s. In this connexion it may be noted that the feedback loop of a class AB amplifier may

* *Research Department, B.B.C. Engineering Division.*

† *Patent No. 514729: C. G. Mayo, H. D. Ellis, R. H. Tanner.*

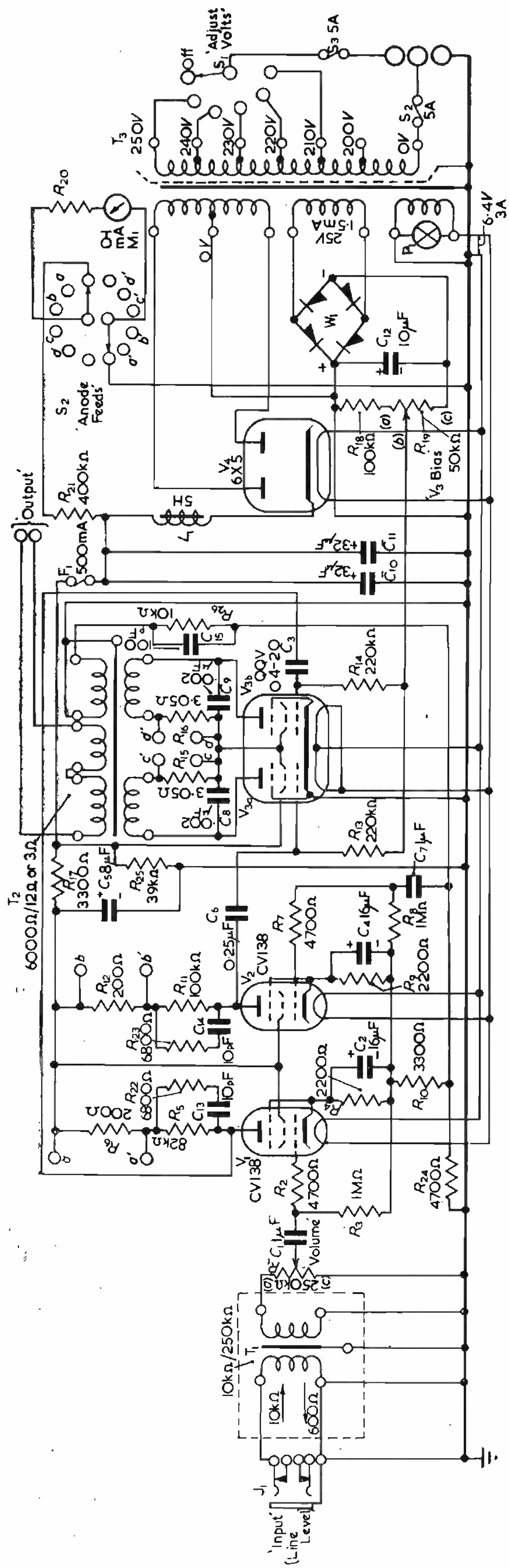

Fig. 1. Circuit diagram of the 7½ watt amplifier

have two different characteristics at high frequencies (three, if the output transformer is not electrically symmetrical), corresponding to the cases (a) when both halves of the output transformer primary winding are simultaneously in action and (b) when one half of this winding is idle, a condition which occurs during part of each cycle when the amplifier is delivering its full output. Stability tests were made to cover both regimes.

The loop gain measurements below 50c/s were made by temporarily "scaling up" all reactive circuit components by a factor of eight, so that tests could be made at eight times the frequency. Thus the interstage, decoupling and cathode by-pass capacitors were reduced to an eighth of their normal value. It was not convenient to reduce the inductance of the output transformer eight

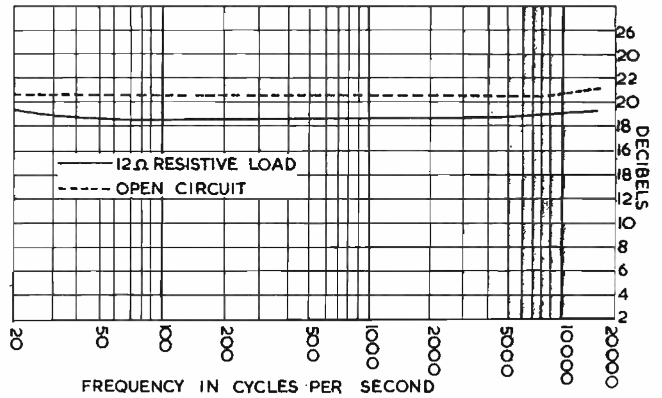

Fig. 2. Gain/frequency characteristic

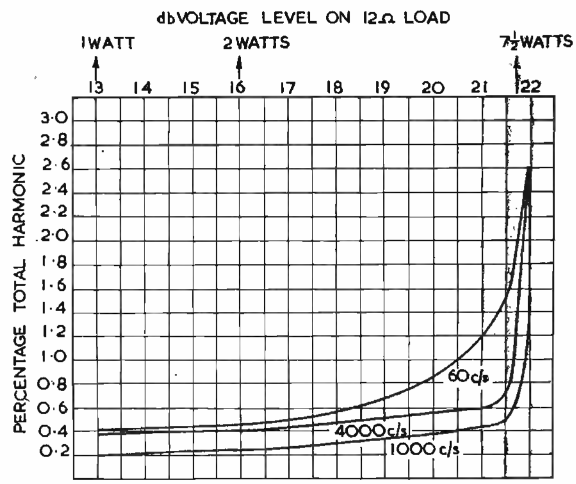

Fig. 3. Total harmonic distortion

times, but the equivalent effect was obtained by increasing the amplifier load in the same ratio; in the case of a pentode or tetrode output (constant current), the effect is the same provided that allowance is made for the resulting change of gain.

The resistance-capacitance combinations R_{22} and C_{13}, R_{23} and C_{14}, and capacitors C_8, C_9 and C_{15} were introduced to bring the loop gain and phase shift characteristic above 20kc/s to the form required for stability.

The gain of the feedback loop in the working frequency range, with the amplifier terminated in its optimum load, is 25db.

H.T. Supply

The largest single item in the amplifier is the mains transformer T_3 and various expedients were considered for reducing this component to a size in keeping with the other circuit elements. One method of achieving the desired end is to have the transformer designed to run at about 120°C., but the temperature inside the case then becomes too high for some of the other components. Without going to this extreme, however, a small economy of space was obtained by taking advantage of the intermittent nature of the H.T. load, which varies from 37mA rectified current with no signal to 95mA with the amplifier delivering 7½ watts of tone. The signals applied to the amplifier usually consist

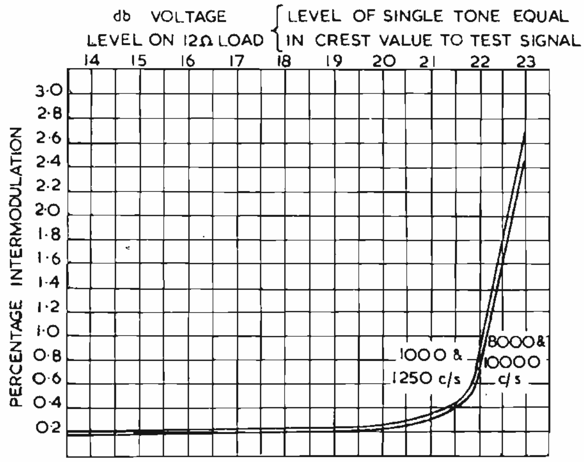

Fig. 4. Intermodulation distortion

of tone pulses, programme or continuous spectrum noise which has a relatively high peak/mean ratio, while initial adjustments to equipment are commonly carried out with a steady tone at a level some 8db below the maximum to be used in the test. The H.T. load for the latter condition is 50mA and a similar average figure was obtained when the amplifier was used to feed programme to a resistive load. As a compromise, therefore, the mains transformer was rated to give less than 40° C. temperature rise with 50mA rectified current.

The H.T. rectifier was also chosen on the basis of intermittent load. In the first models, a cold cathode rectifier rated at 75mA D.C. was used, but there was difficulty in ensuring reliable striking on light load, especially with fluctuating supply voltage, and a change was therefore made to a hot cathode rectifier type 6X5. The 6X5 valve is rated at 70mA D.C. and can withstand 450V between heater and cathode; no separate heater winding was therefore required and it was sufficient to increase the rating of the existing heater winding by about 30 per cent.

The H.T. rectifier works into a choke input filter; the choke L_1 is a miniature component similar in construction to that referred to in Part I. Although, as already stated, the D.C. rating of the rectifier valve is intermittently exceeded, the measuring peak current is always within the 210mA allowed by the makers.

Grid bias for V_3 is provided by a selenium rectifier W_1 operating from a separate 25V 1.5mA winding on the mains transformer.

Performance

The following test figures were obtained on the first model of the amplifier, with the output transformer connected as for a 12 ohm load.

GAIN: 18.5db (volts). Single frequency input required to give 7½ watt output with gain control at maximum: 1.1 volt R.M.S.

INPUT IMPEDANCE AT MID-BAND: 10,000 ohms resistive.

OUTPUT IMPEDANCE AT MID-BAND: 2.2 ohms resistive.

FREQUENCY CHARACTERISTIC: See Fig. 2. The frequency characteristics in the on-load and open circuit conditions are very nearly the same, as the output impedance is nearly constant over the working frequency band shown.

NOISE: Unweighted noise output measured with rectifier voltmeter: −51db with reference to 0.775V R.M.S. (i.e., more than 72db below maximum output).

DISTORTION: The harmonic distortion for single tone input at 60c/s, 1,000c/s, and 4,000c/s is shown in Fig. 3. Oscillographic examination shows the waveform to be free from discontinuities up to the overload point of 7½ watts.

For a class B or class AB amplifier, it is particularly important to test for high frequency distortion caused by inadequate coupling between the two halves of the input transformer primary. A test for harmonic distortion with 10kc/s fundamental is liable to be misleading since some of the distortion products may be outside the pass band of the amplifier and may thus be heavily attenuated. Intermodulation tests were therefore made with two tones of equal level, having frequencies of 8kc/s and 10kc/s measuring the R.M.S. sum of all distortion products below 8kc/s. The results are shown in Fig. 4 together with a corresponding curve taken with tones of frequencies 1kc/s and 1.25kc/s. The two curves are identical within the limits of experimental error; it would therefore appear that the distortion in the 8kc/s to 10kc/s region is no higher than that occurring in the middle of the pass band.

Mechanical Layout

Fig. 5 shows the amplifier mounted on a standard carrying case uniform in size with that used for the rest of the equipment described in earlier articles of this series. The amplifier does not completely fill the case, but the remaining space is used to accommodate spare valves and fuses which are plugged into a series of sockets mounted on a sub panel (removed for the purpose of the photograph).

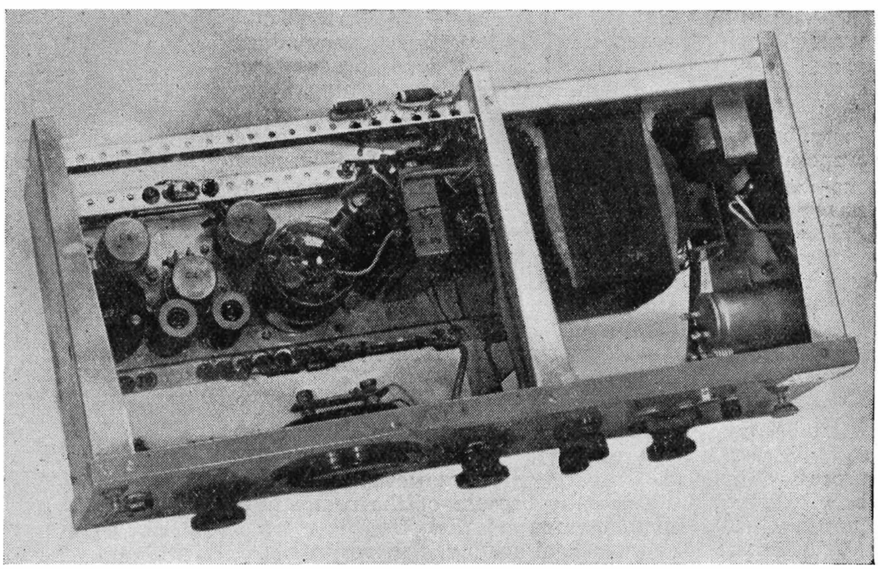

Fig. 5. The complete amplifier

Since this amplifier was designed, mains transformers of the C-core type have become generally available. The mains transformer appearing in this photograph has been redesigned to take advantage of the improved core material, with a reduction in volume of 45 per cent.

The Deposition of H.F. Crystal Electrodes by Vacuum Coating

By L. Holland *

FOR various reasons it is desirable that the electrodes used on high frequency quartz crystal plates should be thin metal films which are in intimate contact with the crystal surface. To produce such an electrode it has been an established procedure to sputter in a glow discharge a thin gold film on to the crystal surface. Allowance must be made for a change in the characteristic frequency of a crystal vibrating in the thickness shear mode (i.e., AT and BT plates) when the electrodes are deposited and in practice a final specified frequency has been obtained by two methods, both of which are described by Spears.[1]

(i) a preliminary sputtered film is deposited and the crystal frequency checked, the desired frequency then being obtained by additional sputtering under carefully controlled conditions;

(ii) the sputtered film acts as a support for a thicker electroplated film which can be removed gradually if required in a cyanide bath until the correct frequency is obtained. The latter method which is generally used in this country is an involved and costly procedure.

The recent interest in the use of vacuum evaporation for adjustment of the crystal frequency is not surprising since measurement of the crystal frequency can be made simultaneously with the deposition and rapid frequency adjustment obtained. Vigoureux and Booth[2] describe a combined sputtering and evaporation plant for crystal coating, Sykes[3] and Parrish[4] have reported the use of vacuum evaporation for adjustment of the final crystal frequency. A special evaporation plant employing a turret head of vacuum chambers is constructed for crystal coating by the Constantin Company of America.

The author's interest in the coating of crystal vibrators is limited to that of the vacuum coating plant used, the design and control of which form the subject of this report. Sputtering and evaporation techniques are well described elsewhere and this discussion is therefore restricted to those procedures of importance for crystal coating.

The Sputtering Process

The deposition of gold on to quartz crystal plates by cathodic sputtering is still widely used in this country. The process, although less rapid than vacuum evaporation, has been preferred until recently because of the comparative simplicity of the apparatus required.

A plant designed for crystal coating is shown in Fig. 1, the vacuum chamber of which is exhausted by means of a rotary pump to a working pressure for the glow discharge of 0.08mm Hg. Good quality gold films can be deposited in an air discharge and thus a supply of inert gas is not necessary as in the case of some metals, e.g., platinum, palladium, etc., which are rapidly oxidized in an air discharge and even by traces of oxygen degassed from the chamber walls. For the sputtering of the latter metals diffusion pumping to thoroughly degas the system together with a controlled supply of inert gas into the sputtering chamber is essential.[5] It should be noted that a diffusion pump has the additional advantage of acting as a barrier to rotary pump oil vapour entering the chamber where it can be decomposed by the glow discharge.

The design of the vacuum chamber and discharge electrodes is shown in Fig. 2. The cathode electrode is suspended on insulators connected to the inside of the chamber lid. The positive side of the H.T. supply, used for operating the glow discharge, is earthed so that both the chamber baseplate and lid comprise the anode electrodes. The negative side of the supply is taken into the chamber via a vacuum sealed insulated electrode and connexion to the cathode is made by a spring loaded contact which disengages when the lid is opened for loading.

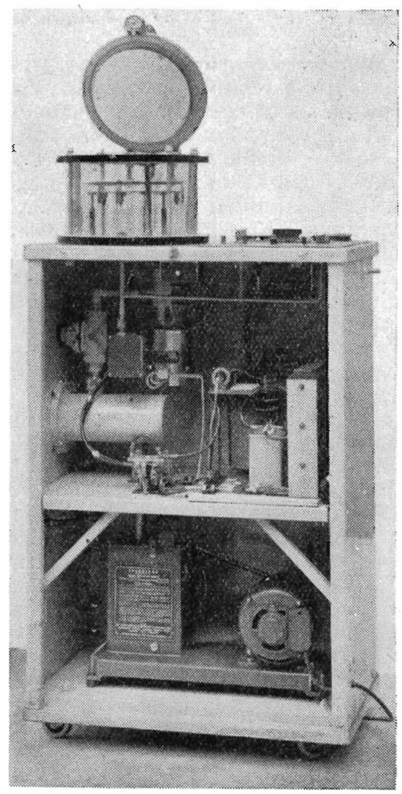

Fig. 1. Interior view of sputtering plant

Showing the exhaustion equipment and high tension power supply. The cathode is attached by insulators to the chamber door, which is open.

Electrical power can be economized by suppressing the unwanted glow discharge from the cathode face adjacent to the chamber lid since this does not usefully contribute to the coating of the crystal surfaces. This is achieved by making the gap separating the cathode and lid (i.e., the anode) less than the electron path length required for a sustained discharge.[6] A similar shielding method is used for the negative lead-in electrode which is surrounded by an anode tube. This method of shielding obviates the need for insulating sleeving such as glass or ceramic beads which invariably break down when a conducting film of gold is formed on their surfaces.

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Uniformity of Sputtered Film

The mean free path of air at the sputtering pressure is in the region of 0.5mm, consequently sputtered atoms will have many collisions with gas molecules before they are trapped on intercepting surfaces. Although the sputtered atoms may leave the cathode with appreciable energies, an effect which depends on the energy of the positive ion bombardment, this initial energy is rapidly lost by collisions with gas particles and the sputtered atoms then diffuse through the discharge gas. Fig. 3 shows the film distribution obtained on plane receiving surfaces arranged parallel with a 20cm diameter cathode and a 40cm diameter cathode.

In both cases the fall off in the film thickness at the edges of the receiving surface is due to diffusion of sputtered atoms which are ultimately trapped on the chamber wall, an effect which would not occur if the cathode and receiving surfaces were endless planes so that every atom leaving the cathode must then be deposited on the receiving surface.[5]

The film distribution obtained on individual crystal planes will be further modified if masks are used to shield the crystal edges, thus a thick mask will produce a curved film distribution with a sharp fall off at the mask edge. The reason for this can be explained in terms of the diffusion

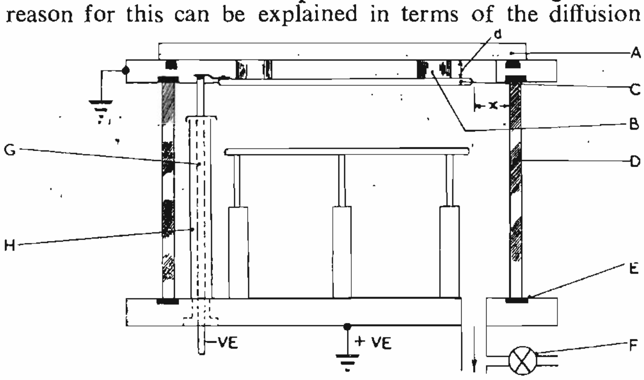


Fig. 2. Sputtering chamber layout

(A) chamber door. (B) insulator. (C) cathode. (D) glass cylinder. (E) rubber seal. (F) needle valve. (G) -ve connecting rod. (H) discharge shield tube. A glow discharge from the upper surface of the cathode is prevented by making the gap (d) between cathode and anode, less than the length of the cathode dark space. Crystals to be coated are placed on the tripod table.

of sputtered atoms in the discharge gas because the edge of the mask normal to the crystal surface is an additional surface for trapping diffusing atoms and thus reduces the number of atoms reaching the crystal plane. The masks used must therefore be very thin or tapered at the edge to avoid affecting the film distribution; similar masks are used in the evaporation process, but in this case the vapour atoms tend to travel in straight lines and the masking action is analogous to light shadows cast by an edge using an extended light source.

Attention has been drawn by Guntherschulze[7] to the influence of the chamber walls on the cathode current-density when the chamber walls penetrate far into the cathode dark space (see dimension "X" in Fig. 2). Dead zones are formed on the cathode because of the restricted electron ionization paths near the wall and the discharge is concentrated at the centre of the cathode, the film distribution then resembles that for a smaller diameter cathode. Similarly the distribution and spluttering rate is altered if the work plane enters the cathode dark space and it may also lead to undesirable heating of the work surface.

Control of the Sputtering Rate

Spears[1] has shown that for high frequency crystals a relation between frequency change and sputtering time can be determined and used for the final adjustment of the crystal frequency. Since this relation must be determined by routine checking of a number of crystals it cannot be expected to hold extremely accurately for any one crystal. Slight changes in the cathode surface conditions, e.g., con-

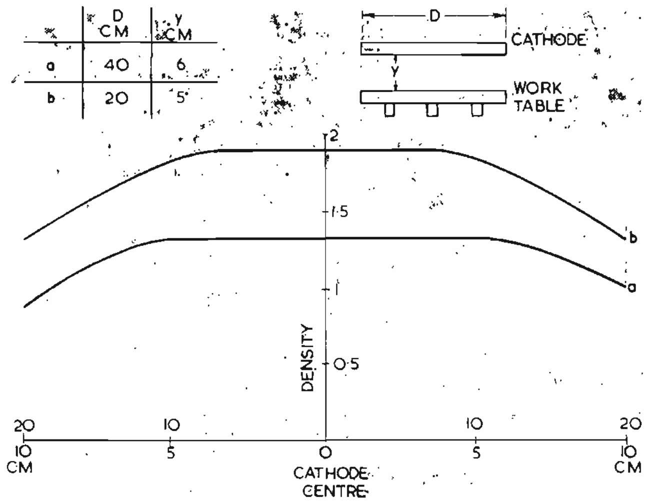


Fig. 3. The distribution of a sputtered film for two cathodes of different diameters

This is shown by plotting the optical density of the deposited film measured across the diameter of the receiving plane. Cathode (a) was operated at 3kV with a current density of 150 $\mu A/cm^2$ and cathode (b) at 1.5kV 500 $\mu A/cm^2$.

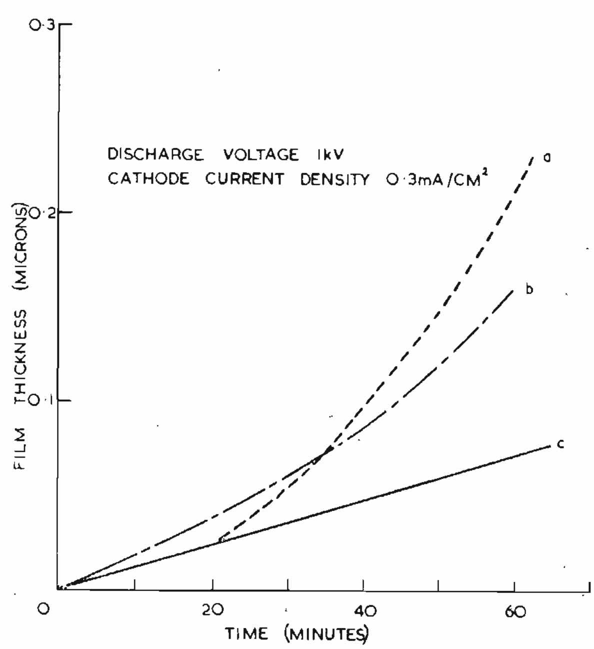
tamination by organic compounds, etc., and in the discharge gas composition must obviously affect the sputtering rate.

There are many factors which must be considered if repeatable results are desired; the effect of slight changes in the gas density, cathode temperature, and input power on the deposition rate is shown by the following experiments using a gold cathode:—

(1) For a particular arrangement of cathode, etc., the rate of deposition is controlled by the voltage and cathode current density and this in turn is dependent on the gas density. Since the temperature of the glow discharge will increase appreciably with sputtering time the gas pressure must be adjusted to maintain the gas density and hence constant voltage and current density. The pressure adjustment is easily made during the sputtering by control of a

Fig. 4. The way in which the deposition rate changes with the sputtering period

In curve (a) the increase in the deposition rate is due to changes in both gas density and cathode temperature as the sputtering proceeds; in curve (b) the gas density is constant throughout, but the cathode temperature is increasing with time; in curve (c) both cathode temperature and gas density do not vary and the deposition rate is constant.



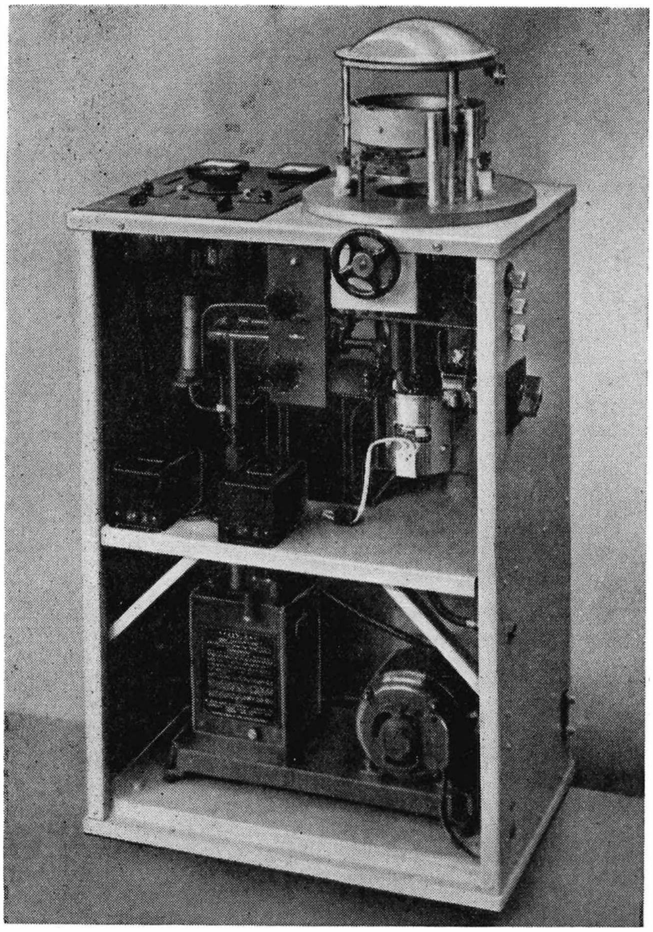


Fig. 5. Interior view of evaporation plant showing diffusion and rotary pumps
Crystals are placed on the spherical holder and coated from a single vapour source at the base of the tripod.

needle valve. The effect on the deposition rate of holding a steady gas pressure and allowing the voltage and current density to change with the gas temperature variation is shown in Fig. 4 curve (a). The effect of the rise in temperature on the gas at constant pressure is to lower the density and with the H.T. supply employed there is then a rise in the discharge voltage which alters the rate of deposition.

(ii) Not all the change in the deposition rate is due to gas density differences, as is shown by comparing curves (a) and (b) where a change in deposition rate still occurs even with constant gas density; this shows that there are temperature-dependent variables other than the gas density. (iii) In the case of curve (c) the specimen was sputtered for equal periods and before being resputtered the cathode was allowed to cool, thus holding the cathode temperature rise steady for each sputtering period as the film thickness increased, this curve is almost linear. Whether the change in deposition rate shown in curve (b) is due to gradual clean up of the cathode with temperature rise or the manner in which temperature effects the liberation of the cathode atoms in the spluttering phenomena, is not clear. It does prove that if the cathode temperature varies as sputtering proceeds then the mass deposited is not a linear function of time.

Evaporation Process

Reference has already been made to the very high rates of deposition possible with the evaporation process and although the technique requires lower pressures than sputtering, i.e., $10^{-4} - 10^{-5}$mm Hg, such pressures are easily obtained with present high speed oil diffusion pumps. A modern plant that has been used for coating crystals is shown in Fig. 5.[8] The chamber is exhausted by a silicone oil diffusion pump having a baffled speed of 50 litres/sec and 10^{-4}mm Hg can be reached in 10 minutes total pumping time. For base coating crystals where frequency control is not involved, e.g., low frequency crystals, the chamber arrangement shown in Fig. 5 can be used. (It may be of interest to note that the author has used this arrangement successfully to aluminize rochelle salt crystals without dehydration of the crystal).

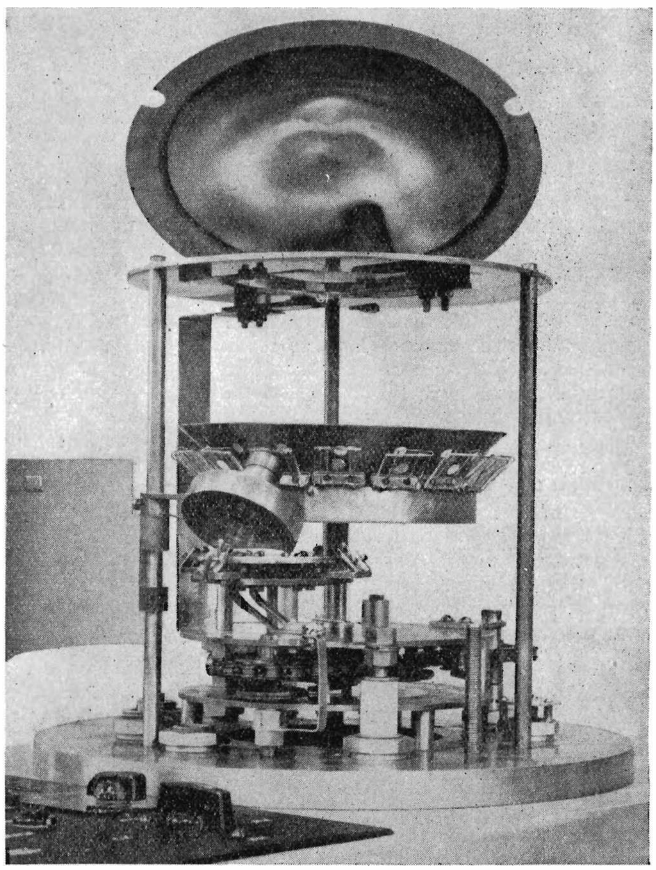
CRYSTAL FREQUENCY CONTROLLED COATING

The high deposition rate and ease of control of the evaporation technique, compared to cathodic sputtering, makes possible the direct frequency adjustment of high frequency crystals during the coating cycle, thus avoiding the necessity for secondary processes such as electroplating already described. Some manufacturing methods employ a stabilizing period after base coating and before the frequency adjustment is made so that it may not be possible always to coat directly to the required frequency.

In one type of equipment used in America for either base coating or frequency adjustment a rotary table with three coating chambers is employed. Each chamber is connected in sequence to the rotary and diffusion pumps and finally arrives, as the table rotates, into the coating position. The pumping system of this type of plant is, however, complex and costly.

In view of the demand for a crystal frequency control unit, the author has recently designed a plant in which a simpler solution of the problem was found by mounting a number of the crystals to be calibrated inside a single vacuum chamber, within which each crystal could be

Fig. 6. Crystal frequency control unit
The control assembly stands on the baseplate of an evaporation plant and is shown with the crystals on the Perspex turret head. The vapour source used for controlling the crystal frequency is on the left-hand side of the unit.



rotated into the coating position by a sealed drive. A description of such a unit follows.

CRYSTAL FREQUENCY CONTROL UNIT.

The control unit, which is designed for use inside the vacuum chamber of a plant similar to that shown in Fig. 5, is constructed so that it can be used for either the final freqeuncy adjustment of crystals already base coated or for the complete coating and frequency adjustment to be made in one cycle.

The H.F. crystals are mounted on a turret head arranged inside the vacuum chamber together with a mechanism, externally controlled, for rotating each crystal into the calibration position. The turret consists of a large Perspex disk with its circumference drilled and fitted with spring loaded connexions for holding crystals mounted on a standard base, e.g., type 10XJ (Figs. 6 and 7). A conical shaped mask with its aperture parallel to the surface of each crystal, is fitted on the top surface of the Perspex disk. With this arrangement one face of 16 crystals approximately ½in. square can be coated in a single evaporation from a source located at the top of the vacuum chamber, approximately 1gm of gold being vaporized to

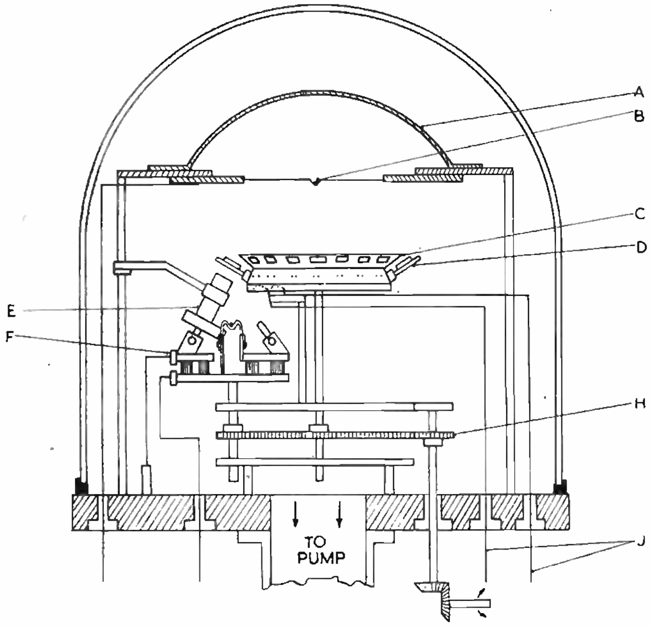


Fig. 7. Layout of frequency control unit

(A) vapour shield. (B) evaporation filament. (C) crystal mask. (D) crystal (E) shield tube. (F) multi-filament head. (H) chain drive. (J) oscillator connexions. The crystal holder and multi-filament head are rotated into the frequency control position by a sprocket and chain connected to a vacuum-sealed shaft in the baseplate. Clockwise rotation moves a new crystal into position and anti-clockwise rotation changes the evaporation source.

deposit a film 0.2μ thick. To ensure a uniform film, the crystal faces are arranged so that the vapour emitted by the evaporation source is normal to the crystal surface and to obtain this the crystals are inclined to the plane of the jig as shown in Fig. 7.

The remaining face of each crystal is then coated individually and the frequency calibration made. To economize on the use of metals such as gold the vapour source is brought near to the crystal surface. A single evaporation heater must hold a sufficient charge to coat 16 crystals and would therefore have a large heat radiating area which could raise the crystal temperature, but this is avoided by splitting the charge among four heaters arranged on a second turret head. A further advantage of this arrangement is the freedom from heater breakage. The evaporation source for gold is a molybdenum foil bent into the hair pin shape shown in Fig. 8. The vapour is emitted in a solid angle smaller than 2μ so that the gold deposited on to the chamber walls is less than that normally experienced with filament type heaters. To deposit a gold film approximately 0.2μ thick on to one crystal face a charge of 60mg must be vaporized, the gold deposited on to shields, etc., can, of course, be recovered after a number of crystals have been coated

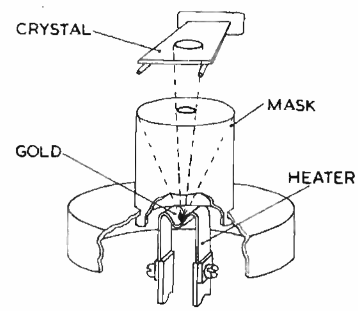
The crystal electrode mask consists of a short tubular shield with the required aperture shape at one end. The evaporation heater is not completely enclosed by the shield tube because the pressure in the tube rises with degassing when evaporation commences, and the vapour aperture is insufficient for obtaining adequate pumping speed. Additional shields are therefore fitted around the vapour source to prevent conducting films being deposited on the Perspex plate.

For measuring the frequency during the evaporation each crystal makes connexion with a pair of spring loaded contacts under the Perspex holder, which are wired to an external test oscillator via glass to metal seals mounted in the baseplate. For very high frequency crystals the length of connecting leads could possibly be reduced by mounting an oscillator in a vacuum tight container inside the vacuum chamber.

The Perspex holder and vapour source turret head are rotated into position by a sprocket and chain connected to a vacuum sealed shaft in the baseplate. The sprockets on both the turret head and crystal holder shafts are of the freewheel type and mounted in opposing positions, independent movement of both shafts is then obtained by a single

Fig. 8. The vapour sources used on the multi-filament head

These are made from molybdenum foil and with the construction shown most of the vapour is confined to a small angle.



external control handle, i.e., clockwise rotation moves a new crystal into the calibration position and anti-clockwise rotation changes the evaporation source.

Conclusions

The present method of frequency adjusting H.F. crystals by the combined cathodic sputtering and electro-plating techniques can be largely replaced by the single operation of evaporation coating. A limiting factor in the use of the evaporation method for controlling very high frequency crystals is the capacitance of the crystal leads, but most likely a solution of this will be found in due course. The unit described has, however, been used successfully for coating and calibrating 4Mc/s crystals.

Acknowledgments

The author wishes to tender his acknowledgments to Mr. A. S. D. Barrett, Technical Director of W. Edwards & Co. (London) Ltd. for kind permission to publish this account, also to Mr. R. A. Spears of Automatic Telephone & Electric Co., who kindly co-operated in the preliminary testing of the crystal frequency control unit and to Mr. J. Harris and Mr. K. Yates who made many valuable suggestions during their construction of the apparatus.

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Counting-rate Meters

By G. D. Smith *

THE counting-rate meter, or to give it the name by which it is more commonly known, the ratemeter, is an instrument for measuring the mean rate of arrival of pulses over a period of time. It is essentially a frequency meter, but differs from the majority of such instruments known to electronic engineers in that it measures inputs which are not necessarily recurrent waveforms. One of the main uses of ratemeters is to count the emanations from radioactive materials, which occur at rates random in time. Equipments designed for this purpose have been in use over the last two decades and during that time there has been a steady improvement in performance.

Most readers will be familiar with various types of scaling circuit for pulse counting; the great advantage of a ratemeter compared with a scaling unit is that a direct indication of counting rate is obtained. The use of a ratemeter for giving rapidly an approximate measurement of counting rate is an accepted procedure; the purpose of this article is to describe the principles of such instruments, and to show that an accurate ratemeter employing the most recent improvements in method is an invaluable asset to any laboratory engaged in nucleonic investigations. The treatment here is by no means exhaustive and the references listed give much additional information.

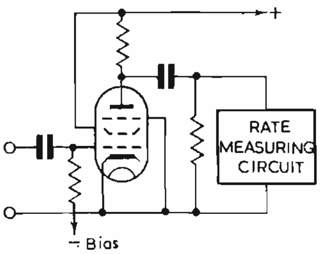


Fig. 1. Pentode limiter for pulse levelling

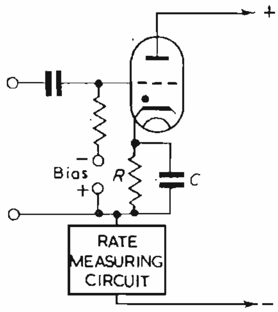


Fig. 2. A thyratron used for pulse levelling

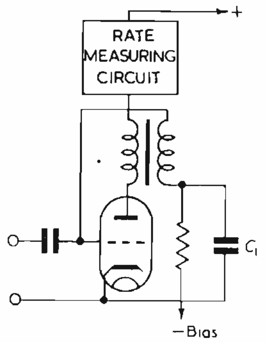


Fig. 3. Blocking oscillator for pulse equalizing

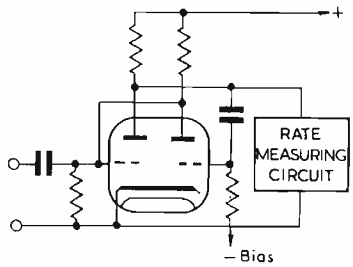


Fig. 4. A single shot multivibrator for pulse equalizing

The primary requirement of a ratemeter is that each measured input pulse shall contribute equally to the final measurement; this generally means reduction to a constant amplitude and duration. Having achieved this, the equalized pulses are then averaged; in the simplest case this may be carried out by means of a meter with very heavy damping. It is more usual, however, to integrate, smooth and measure the average rate in a circuit consisting of capacitive and resistive elements in parallel. The mean voltage appearing across the capacitor, or the mean current through the resistor then representing the appropriately weighted figure for the mean rate of pulse arrival.

Pulse Shaping

There are many possible methods of pulse shaping, and some examples will be considered briefly.

A simple procedure is to limit the amplitude by applying large negative pulses to the grid of a valve so that the anode current is completely cut off, and to obtain a definite pulse duration by differentiation (Fig. 1). Stability is dependent upon H.T. voltage and valve characteristics remaining constant.

* *E. K. Cole, Ltd., Electronics Division.*

A thyratron can be used for pulse levelling[1] (Fig. 2). A positive pulse of suitable amplitude applied to the grid will trigger the valve. The anode current surge charges capacitor *C*, reducing the anode-cathode potential and driving the grid negative with respect to cathode. This cuts off the anode current, and the capacitor discharges through resistor *R* to restore the original conditions. The duration of the input pulse must be appreciably less than the time constant *CR*, or spurious discharges will result. This condition may be met by differentiation at the grid. Current pulses are now being supplied to the rate measuring circuit; amplitude is constant at a value dependent upon the characteristics of the thyratron, and the duration constant at a period governed by the values of *C* and *R*. The time constant *CR* must be above the minimum value required to ensure thyratron extinction; this determines the resolution time, that is, the minimum permissible time between successive pulses to enable both to be counted. By suitable switching of *C*, a linear response can be obtained up to 30,000 pulses per second with a periodic input, i.e., minimum spacing between pulses $30\mu S$.

Another approach is to use the input pulses (differentiated) to trigger a blocking oscillator.[3] The oscillator grid is normally biased beyond cut-off; each positive input pulse produces a pulse at the anode dependent solely upon the circuit constants of the oscillator. The mean anode current is then an indication of counting rate. The duration of the oscillator pulse may be varied by switching values of *C* (Fig. 3), thus covering different input ranges.

A single-shot multivibrator may be used for pulse equalizing.[2] Fig. 4 shows a circuit of this kind. The output pulse is dependent upon the circuit constants of the multivibrator.

Such a system could be used with a meter in the anode of the right-hand valve as a very simple ratemeter in circumstances where size and weight must be a minimum; for example in surveying for radioactive materials or checking contamination. The return time-constant of the multivibrator would have to be large enough in relation to the mean spacing between pulses to give a readable mean current; some proportion of input pulses would then be lost during the circuit dead time. The duration of the input pulse must, in any circumstances, be less than the multivibrator time constant.

Fig. 5 shows a more elaborate input circuit, which has a low resolution time. V_1 is biased to cut-off; positive input pulses are differentiated on the grid. The negative pulse on the anode is applied across a ringing coil; overswing is suppressed by a diode V_2. The narrow pulse then triggers an Eccles-Jordan flip-flop, V_1. The grids of V_4 are tied to the grids of another double triode, whose common cathode is connected through a suitable resistor to a negative reference line. Each half of V_5 is alternately switched on and off, as the grid swing of V_4 extends from negative cut-off to grid current limiting in the positive direction. The current switched on, and thence the amplitude of the voltage pulses at the anode, depends almost entirely on the negative reference line for its stability. Pulse duration is equal to the interval between successive input pulses; this is a suitable form to apply to an integrating circuit as in Fig. 7.

In any counting system or counting-rate measurement, some proportion of a random pulse input will be lost during the dead time of the input circuit. The number of counts lost will be given by the interval law. If resolution time is τ sec, true counting rate N and observed rate N_1 counts per sec, then

$$N/N_1 = 1 + N_1\tau \quad \ldots\ldots\ldots\ldots\ (1)$$

Rate Measuring Circuits

The circuits employed for integrating, smoothing and averaging—often loosely described as integrating circuits—

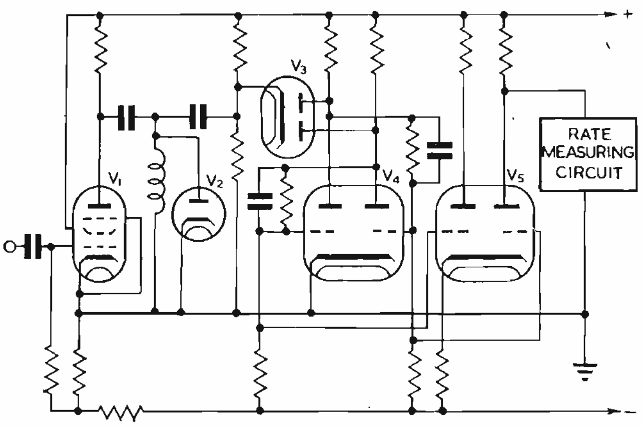


Fig. 5. Input circuit with low resolution time

consist essentially of a capacitance shunted with a resistance.

Consider first the integrating function; a pulse input as in Fig. 6(a), is fed to capacitor C through resistor R_1, which is effectively infinite during the interval between pulses (for example, a pentode valve, a switched triode or pentode or a coupling diode). The voltage developed across C (V_c) will be as in Fig. 6(b); it will continue to rise until the input circuit fails to deliver the pulse current.

If capacitor C is now shunted by a resistor R which is of such a value that CR is a time constant large compared with the average time interval between pulses, V_c will rise until the mean flow of current into the capacitance is counterbalanced by the mean discharging current through resistor R, when it attains an equilibrium value. (Fig. 7(b)).

The functioning of the arrangement can be explained by considering its electrical equivalent, Fig. 8. A pulse generator of voltage I_pR and zero impedance feeds C through R. V_c obviously cannot rise above the value I_pR; the effective pulse voltage progressively decreases with the arrival of each successive pulse; the rate of charging likewise decreases, with the smoothing effect already shown in Fig. 7(b).

The mean value of V_c is a measure of the mean rate of arrival of pulses, and the extent to which any reading of this voltage is affected by pulses previously received is governed by the choice of time constant. As the product CR is increased in value, so the ripple becomes smaller in amplitude, and at the same time the "memory" of the circuit is increased in length.

Various refinements of the basic circuit, together with the theoretical considerations governing the choice of values will now be studied. From this survey, the reasons underlying the choice of circuit used in a practical instrument will emerge.

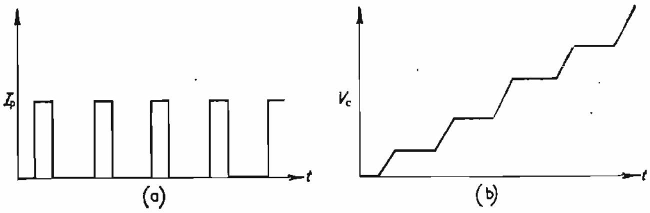


Fig. 6(a). Input pulse. (b) Voltage developed across C (V_c)

If q is the charge deposited in capacitor C by each pulse, the transient appearing across the capacitor is of the form

$$v = q/C\ \varepsilon^{-t/CR} \quad \ldots\ldots\ldots\ldots\ (2)$$

Assuming that input pulses have been integrated over a time sufficient to reach equilibrium, the mean value

$$V_c = n\int_0^\infty v\,dt \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3)$$

$$= n\int_0^\infty q/c\ \varepsilon^{-t/CR}\,dt = n\left[-\frac{qCR}{C}\varepsilon^{-t/CR}\right]_0^\infty$$

$$= nqR \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (4)$$

An extension of the basic "integrating" system is shown in Fig. 9. The valve is biased beyond cut-off; positive input pulses cause anode current to flow. The effect of C and R is as previously described. The pulse current is, of course, dependent upon valve characteristics, control and screen grid potentials, and the amplitude and duration of input pulses. Variation of screen grid potential forms a convenient means of range changing.

Fig. 10 is known as a diode pump integrating circuit; in this circuit the charge deposited in the integrating capacitor for each input pulse is a more definite amount. If the input source impedance (e.g., the anode load of the driving valve) is R_i, the duration t of the input pulse is not critical provided that the coupling capacitor C_i becomes

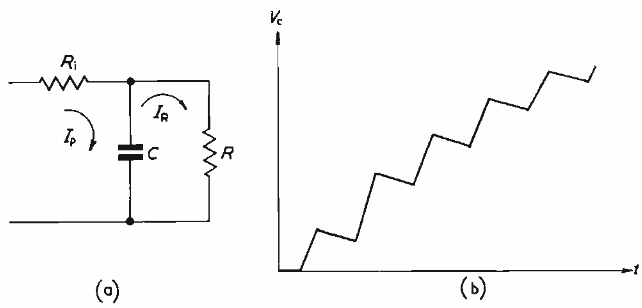


Fig. 7(a). Integrating circuit. (b) Waveform of V_c

fully charged before the end of the pulse. Ignoring the impedance of D_1, this condition is effectively met provided that $t > 6C_iR_i$. If no anode current is flowing in the driving valve, its anode will be at H.T. line potential. C_i will be charged to the full H.T. line potential through D_1. A positive pulse to the grid of the driving valve lowers its anode voltage by E volts, and a quantity $q = EC_i$ is transferred from C_i to C through D_2. From Equation (4)

$$V_c = nEC_iR \quad \ldots\ldots\ldots\ldots\ (5)$$

If the valve voltmeter input (V_s) required to give a full scale reading has been determined in design, then the full scale frequency

$$n_s = \frac{V_s}{EC_iR} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

For range switching, the most useful variable, of the factors in Equation (5), is C_i, but to cover several decades it may also be necessary to switch values of R as the capacitances required become impracticable. Since there are a number of possible component tolerances, some form of fine adjustment is necessary to compensate for them; this control can most easily be obtained by varying C_i, V_s (meter sensitivity control) or E (amplitude of output from the driving valve).

If the minimum time interval between incoming pulses (i.e., the minimum duration of input pulses to the diode pump) is such that C_i is not effectively completely charged by each pulse, the voltage output V_c will, of course, be non linear in respect to input rate.

The impedance of diode D_1 has hitherto been disregarded; if C_i is allowed to charge fully, the anode

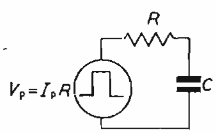


Fig. 8. Equivalent circuit of Fig. 7

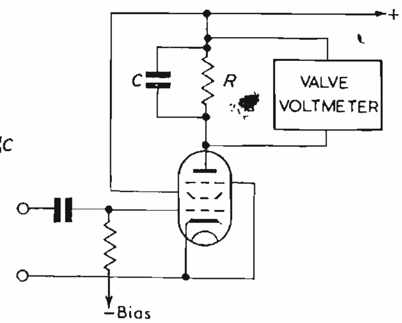


Fig. 9. Simple integrating and measuring circuit

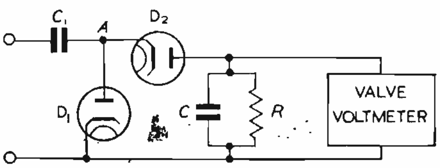


Fig. 10. Diode pump integrating circuit

of D_1 will ultimately reach a potential about 1·4 volts negative with respect of its cathode due to diode contact potential effects. As the anode drifts towards this potential, diode impedance rises. Fig. 11 shows the characteristics of a typical diode with negative anode volts.

If, for example, C_i = 50pF, which would normally constitute a fast range, charging time will be several milliseconds. On high counting rates, point A would, therefore, return to a potential which varied according to pulse spacing, thus causing non-linearity with respect to input rate.

A resistor connected between point A and a positive potential, e.g., 100MΩ from the H.T. line, will ensure that the diode anode current never falls below a few microamperes and the anode potential will not fall below 0.5V negative; the diode impedance will then be such that the charging time of C_i (in the same example of 50pF capacitance) will not be more than 2 microseconds.

As already explained, there is a fluctuation in V_c between pulses; therefore, if the input is random in time, a reading taken at any instant may not be the true average value.

The distribution of pulses in a random input will be in accordance with Poisson's distribution law. The presence of capacitor C means that V_c at any instant involves an integration of all previous pulses, allowing for an exponential rate of decay since the time they occurred. Thus successive observations are not independent of each other, and a special statistical theory is required for ratemeters. This has been discussed fully in various articles,[3,4] but the important derivations will be given here.

The mean square value of the voltage fluctuations is given by

$$(\Delta V_c)^2 = n\int_0^\infty v^2 dt = n\int_0^\infty q^2/C^2\, \epsilon^{-2t/CR}\, dt$$

$$= n\left[-\frac{CRq^2}{2C^2}\,\epsilon^{-2t/CR}\right]_0^\infty = \frac{nRq^2}{2C}$$

The R.M.S. value,

$$\Delta V_c = q\sqrt{nR/2C} \quad \ldots\ldots\ldots\ldots\ldots \quad (7)$$

$\Delta V_c / V_c$ is termed the standard deviation (S.D.)

$$\text{S.D.} = \Delta V_c/V_c = \frac{q\sqrt{nR/2C}}{nqR}$$

$$= \sqrt{\frac{nR}{2n^2CR^2}} = \frac{1}{\sqrt{2nCR}}$$

After the ratemeter has reached an equilibrium condition, the fractional probable error (P.E.) of a single reading is given by

$$\text{P.E.} = 0{\cdot}675\ \Delta V_c/V_c = \frac{0{\cdot}675}{\sqrt{2nCR}} \quad \ldots\ldots\ldots \quad (8)$$

The significance of Equation (8) is that if a large number of observations are made, the error will be less than the

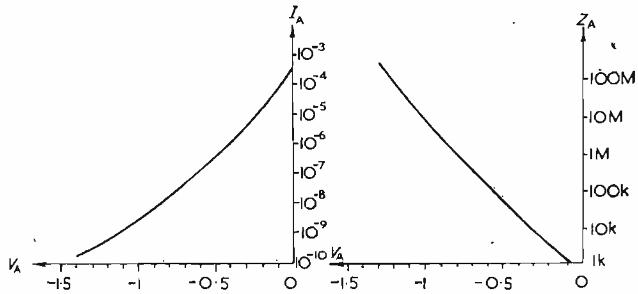


Fig. 11. Characteristics of a typical diode with negative anode voltage

figure given in half of them. Except when the mean counting rate is low, the statistical variations by a Poisson distribution are similar to those by normal law distribution. In this case, the percentage of readings whose errors exceed n times the probable error is

n	Readings (per cent)
1	50
2	18
3	4·4
4	0·7

The amplitude of measured fluctuations may be limited by the failure of the voltmeter to respond fully to the transient, making probable error somewhat less than the calculated figure.

When an input is applied to a ratemeter, it takes some time for V_c to rise to a quasi-equilibrium value. For purposes of calculation we may assume that equilibrium has been reached when the theoretical instantaneous output voltage does not differ from the ultimate mean value by more than the probable error figure.

If the ratemeter is operated over a finite time t_1, from Equation (3),

$$V_c(t_1) = n\int_0^{t_1} v\, dt = n\int_0^{t_1} q/C\ \epsilon^{-t/CR}\, dt$$

$$= n\left[-\frac{qCR}{C}\,\epsilon^{-t/CR}\right]_0^{t_1} = nqR(1-\epsilon^{-t_1/CR}).$$

At a time t_1, V_c differs from its ultimate value by

$$nqR\ \epsilon^{-t_1/CR}$$

If t_1 is the equilibrium time as defined,

$$nqR\ \epsilon^{-t_1/CR} = \frac{0{\cdot}675}{\sqrt{2nCR}}\ .\ nqR$$

$$\therefore\ -t_1/CR = \log_e \cdot 675 - \tfrac{1}{2}\log_e 2nCR$$

$$\therefore\ t_1 = CR\,(0{\cdot}394 + \tfrac{1}{2}\log_e 2nCR) \quad\ldots\ldots\ldots\ldots (8)$$

The equilibrium time can, however, be reduced to very small proportions if a series of integrating capacitors is provided, and those not in use at any time are maintained

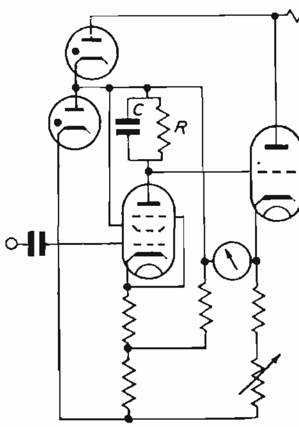


Fig. 12. Cathode follower voltmeter

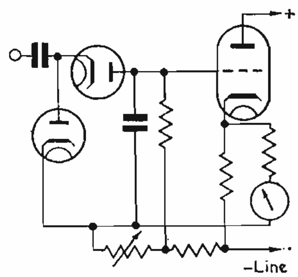


Fig. 13. Diode pump circuit with cathode follower voltmeter

at a potential similar to that existing across the one which is in use. The operating technique is then to commence with the smallest capacitance and switch to successively larger ones as the meter passes through the estimated means of its fluctuations on each position. With experience, this can be done with a high degree of accuracy.

Valve Voltmeter Circuits

This article deals only with linear circuits, that is, those giving an output directly proportional to the mean input rate. A combination of a number of diode pump circuits similar to that in Fig. 10 can be arranged to produce an output proportional to the logarithm of the mean rate.[5]

The voltage developed across C may be measured by a variety of methods. As mentioned earlier, a microammeter can be connected in series with R, provided that V_c/R is a current of reasonable magnitude.

A system of more general use is to apply the voltage V_c to the grid of a cathode follower. Fig. 12 is a method of so doing, when the integrating circuit is at a D.C. potential above earth.[6] Degeneration is included to improve stability. Range switching may be accomplished by the normal variation of R, or by varying the amount of degeneration, or a combination of the two.

Fig. 13, using the integrating circuit as in Fig. 10, requires a negative reference line. The contact potential appearing across the diodes must be suitably backed off, otherwise switching the value of resistance R to vary range will cause a change in the valve voltmeter zero. With a suitable valve, the grid bias can provide the backing off potential. The valve must also have a reverse grid current sufficiently low that no significant potential is developed across the highest value of R.

Fig. 14 shows a voltmeter circuit with exceptional zero stability and one which can achieve a high degree of linearity. VR_1 controls the bias on V_1, and thereby the grid and cathode potential of V_2, thus constituting the meter zero adjustment. Degeneration is applied from the cathode of V_2 to the input grid.

The negative bias (V_g) on the grid of V_1 acts in opposition to the pulse, E, applied to the diode pump circuit. Equation (5) will therefore read in this case

$$V_c = nC_1R\,(E - V_g)$$

If the signal swing on the grid of V_1 is ΔV_g, and the gain to the cathode of V_2 is A, then the voltage variation at the cathode of V_2.

$$V_k = A \times \Delta V_g$$

Total input voltage $V_s = \Delta V_g + A \times \Delta V_g = \Delta V_g\,(1 + A)$

$$\therefore\ V_g = \frac{V_s}{1 + A} \text{ and grid potential of } V_1 = V_g + \Delta V_g$$

With input at a rate n_s, $V_s = n_sC_1R\,(E - (V_g + \Delta V_g))$

With input rate $n_s/2$, $V = n_s/2\ C_1R(E - (V_g + \Delta V_g/2))$

This gives a mid-scale error $\dfrac{25\,\Delta V_g}{E}$ per cent.

Therefore ΔV_g must be as small as possible, i.e., A should be as large as possible.

By including a suitable combination of positive and negative feedback in the circuit, loop gain A can be increased almost to infinity. However, with normal values, e.g., $A = 100$, $E = 50\text{V} \approx V_s$, then $\Delta V_g = 0{\cdot}5V$ and mid-scale error is 0·25 per cent: further improvement is therefore not necessary in the vast majority of instruments.

If a series of integrating capacitors is provided, one side of each should be connected to VR_1 (Fig. 14), and the other side of those not in use connected to a point of negative potential equal to $(V_g + \Delta V_g/2)$. As described earlier, this will enable equilibrium to be rapidly attained at any part of the scale.

Advantages of Ratemeters

In addition to the direct indication of rate referred to in the opening paragraph the ratemeter has other advantages as compared with a scaler.

If a recording milliammeter is used instead of, or in conjunction with, the inbuilt meter, the scope of the instrument is greatly extended. A scaler with a timing unit can only measure the total count in a period; frequent inspection is necessary to check for variations of the counting rate during that period. Information on the variations of counting rate is required in any measurement where the rate is liable to vary, such as in plotting the rate of decay of the activity of a sample, in plotting the characteristics of a counter tube, or in medical tracer work.

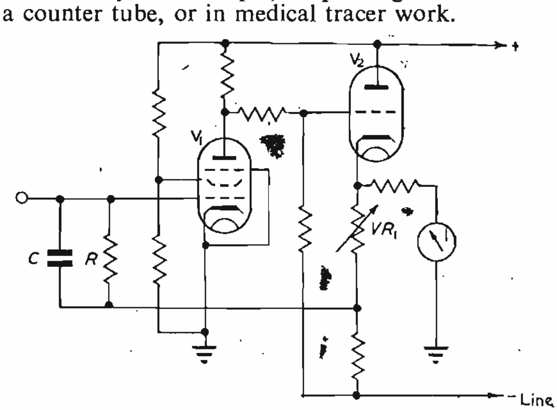


Fig. 14. Voltmeter with negative feedback

Even when a rate is believed constant, errors may arise due to such causes as a physical movement of the sample in relation to the counter, a change in counter characteristics, multiple discharges in the counter or instrument failure. A recording ratemeter provides a check on such errors.

The response time of a recorder is usually such that the fluctuations of reading, and consequently the probable error, will be reduced. An interpretation of the record over a period of time enables a mean result to be obtained with a probable error far less than that for a single observation.

Although a scaling unit may count every pulse it receives, it is still subject to a statistical error when the input is random in time. Assuming that all pulses are counted, in a count taken for t seconds at a mean rate of n pulses per second the probable error will be

$$\text{P.E.} = \frac{67{\cdot}5}{\sqrt{nt}} \text{ per cent} \quad \ldots\ldots\ldots\ldots \quad (9)$$

Calculating the probable error of a ratemeter if the reading is averaged over t seconds and ignoring equilibrium time, the statistical error of the ratemeter during any given time will appear to be less than or equal to that of a scaler.[7] However, the time taken to find an average rate from random information and to a given degree of accuracy is as derived from Equation (9). The impression is therefore misleading, the discrepancy being the time taken to reach condition of equilibrium. With intelligent manipulation of the integrating time constant, to reach equilibrium in a minimum time, the probable ratemeter error should be very little greater than that of a scaler.

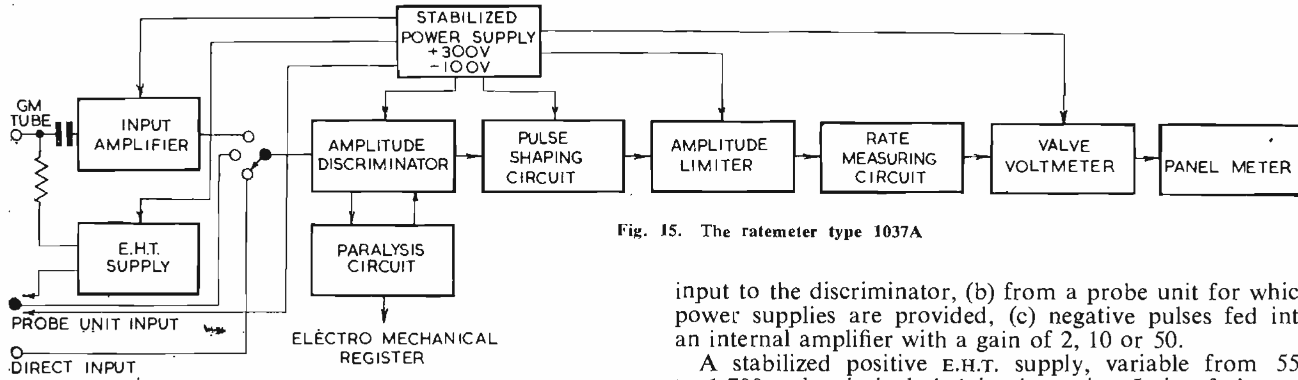
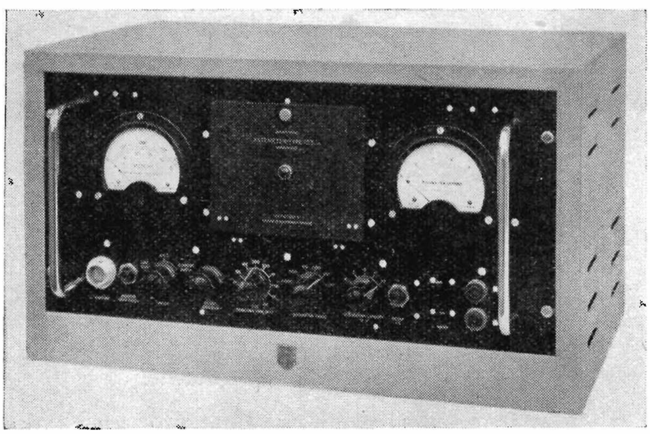


Fig. 15. The ratemeter type 1037A

Ratemeter 1037A

The Ratemeter type 1037A is an instrument with a wide variety of applications and with a high degree of accuracy. Fig. 15 is a schematic diagram of the unit.

The ratemeter circuit in this instrument embodies principles similar to those described in the text. The basic circuits are the pulse shaping system of Fig. 5, a diode pump circuit and a valve voltmeter as in Fig. 14.


The Ekco ratemeter type 1037A

There are six ranges, in decade steps, full-scale rates extending from 1 pulse per second to 100,000 pulses per second. Five integrating time constants are available on each range. Below 100 pulses per second the maximum time constant is 160 seconds.

Circuit accuracy is of the order of 1 per cent. A $3\frac{1}{2}$in. panel meter is included. An external recording meter may be connected; this can be 5mA F.S.D. (or less, suitably shunted) or of the 100mV type. Variation of reading with mains variations of $\pm$ 10 per cent is 0·5 per cent. After an initial warming up period, long-term stability is extremely good.

An input amplitude discriminator is provided which is capable of discriminating against pulses falling below a minimum amplitude; this minimum is variable from 5V to 50V and it can be measured on a second panel meter. A paralysis circuit, giving known dead times from 5μsec to 10msec is included. This discriminator and paralysis circuit is similar to that described by Cooke-Yarborough.[8] When working with the longer paralysis times a relay in the paralysis circuit is closed by each input pulse; this feature enables the ratemeter to be used with an external register as a low speed scaler.

Input may be of any three forms (a) a positive pulse input to the discriminator, (b) from a probe unit for which power supplies are provided, (c) negative pulses fed into an internal amplifier with a gain of 2, 10 or 50.

A stabilized positive E.H.T. supply, variable from 550 to 1,700 volts, is included in the unit. It is of the L.F. Oscillator type, and is intended primarily for Geiger-Müller tubes. E.H.T. voltage may be measured on the same meter as the discriminator bias voltage. Ripple is less than 1mV peak to peak, and stability for mains variations of $\pm$ 10 per cent is better than $\pm$ 1 per cent.

With the addition of only a G.M. tube, this equipment constitutes a complete counting set-up. Any Geiger pulse exceeding 0·1V in amplitude can be counted. A scintillation counter could be used providing that the current drain in the potential divider network of the photomultiplier is kept low. Additional smoothing would be required to use the E.H.T. supply for an ionization chamber followed by a high gain amplifier.

Acknowledgments

The ratemeter type 1037A was developed for the Atomic Energy Research Establishment, Harwell. Acknowledgments are due to the Director, A.E.R.E., and to the Directors of E. K. Cole, Ltd., for permission to refer to the equipment in this article, and to Mr. E. W. Pulsford, and Mr. E. H. Cooke-Yarborough of A.E.R.E. who were responsible for the basic design.

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A Precision Polarograph
for Chemical Analysis

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MODERN chemical analysis employs many electrical instruments of which the polarograph is just one example finding wide application for the analysis of many metallurgical materials. In essence, this instrument measures the current which flows when a pre-determined potential is applied to two electrodes immersed in the solution being analysed, one electrode being non-polarizable and the other, the cathode, a very small metal electrode. Under suitable chemical conditions, the current flowing, which is of the order of microamperes, is a linear function of the concentration of the reducible ions in solution. By reducible ions is meant the ions of those metals which can be deposited at the cathode at the potential applied. An excess of other ions is always present, but as these are not deposited at the cathode they do not contribute to the current which is measured.

To take an example, the solution to be analysed may be one containing cadmium chloride and a hundred-fold excess of sodium chloride. If the two electrodes are placed in this solution and a small potential is applied to them, ions, both sodium and cadmium, will migrate to the cathode. So long as the potential is low enough, deposition of either of these ions is impossible, and to a first approximation no current can flow. As the potential is increased, however, a point is reached at which the cadmium ions, which are more electro-positive than the sodium ions, can be deposited. A current then flows. At this point the current in the bulk of the solution is carried by both sodium and cadmium ions migrating to the cathode, but as the sodium ions cannot be deposited they merely form a dense cloud round the small cathode. However, the cadmium ions in the near vicinity of the cathode are deposited and the current which flows is controlled by the rate at which these cadmium ions are supplied from the bulk of the solution. It can be shown that under these conditions a constant current will flow which is proportional to the concentration of the cadmium ions in the solution.

Typical Polarographic Curve

It is customary to plot the current/applied potential curve for a case such as that which has just been discussed in the form illustrated in Fig. 1. As the applied potential V across the polarographic cell is increased from zero, at first only a very small residual current i_0 flows. When the applied potential reaches the deposition potential V_1, of cadmium in the example taken, the deposition of the cadmium ions permits current to flow, and this current rises rapidly to a constant value. A current "step" is therefore produced of magnitude $i_1 - i_0$; it is this current which it is desired to measure.

If the applied potential is increased further, the current stays constant until the potential reaches V_2, when ions of a second type with a higher deposition potential e.g. zinc, can be deposited. Again, the current step $i_2 - i_1$ produced when all of this second type of ion are deposited is dependent on the concentration of that ion in the solution.

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The Dropping Mercury Electrode

This apparently simple method of determining the nature of ions present in the solution (by the potentials at which the current steps occur) and the concentration of these ions (by the magnitude of the steps) is not so simple to achieve in practice. If one attempted to use a small piece of wire for the cathode several difficulties would be encountered; it can be easily seen that the deposition of metallic ions on the electrode would in effect contaminate it. For this reason, and for others, the so-called dropping mercury cathode is employed in all industrial polarographic analyses. This electrode consists of a minute droplet of mercury suspended on the end of a capillary tube connected to a mercury reservoir. To ensure a continually clean surface, a steady flow of mercury down the tube is arranged, so that droplets fall off and reform every few seconds.

This cathode makes practical polarographic analysis possible, but it obviously complicates the instrumentation. Thus, as the size of the cathode is continually altering, the current which can flow is changing in the lifetime of each drop so that a current waveform (at a fixed potential) of the type illustrated in Fig. 2 is produced. When

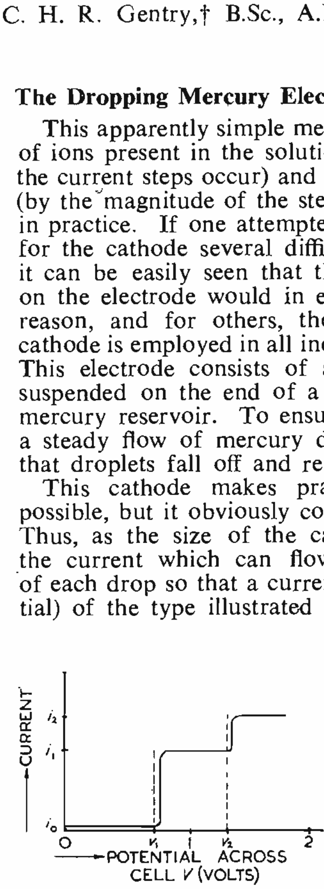


Fig. 1. Current/Applied potential

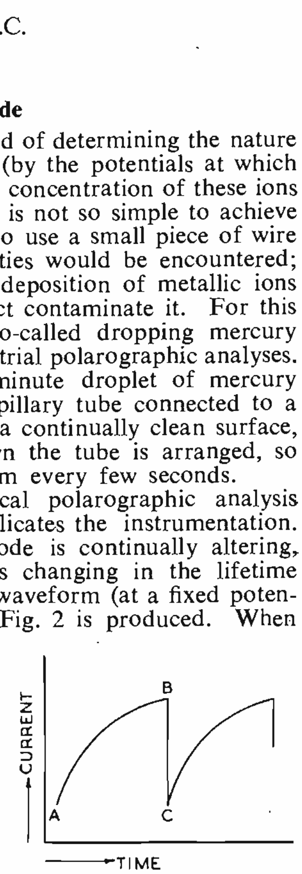


Fig. 2. Current waveform at a fixed potential

a drop is small, a low current, A, flows, but as the drop grows this current increases to a maximum B when the droplet detaches itself and the current falls as at C. Under proper conditions, the current cycle for each drop is identical, but an exact theoretical interpretation of the current-time curve is difficult.

Most commercial polarographs use a sensitive, long-period galvanometer for the measurement of the current and this measures an "average" current during the life of each drop. It is not usually possible to avoid all oscillations of the galvanometer in such a measurement, because if too much damping is used the shape of the current-applied potential curve is substantially altered. This imposes a limitation on the accuracy attainable by such measurement of average current. It is possible to use a galvanometer with a time-constant sufficiently short to follow the full current time curve faithfully, but a simpler and more convenient method is to measure the current only at one point in the life of the mercury drop.

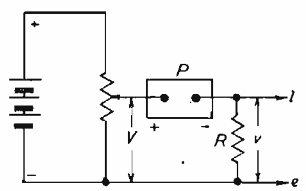
It is apparent that when a drop is detached from the electrode, the equilibrium conditions in the near vicinity are violently upset and in the early life of the new drop the current which flows is difficult to interpret; in fact it has little real physical meaning. But as the drop grows, equilibrium conditions are eventually established and some theoretical significance attaches to the current which is flowing. It is desirable, therefore, to measure the current after the drop has had time to grow somewhat, and from a practical point of view it is easiest to measure the current immediately prior to the severance of the drop.

Methods of Measurement

Conventional polarographs record the required portion of the current-applied potential curve either photographically or by means of a pen recorder. They usually measure the "average" current, although at least one commercial instrument records the maximum current. The precision attainable from these instruments is limited by the size of the recording paper, and it was the present purpose to design an instrument which would give a higher attainable accuracy. From what has already been said, it can be understood that it was preferred to measure the maximum current in the life of each mercury drop.

Use of an Oscillograph for Polarographic Measurement

Although it would be possible to use a D.C. amplifier and recorder for this purpose, the use of a cathode-ray oscillograph has definite advantages, provided that it is not itself used for quantitative measurements, but purely as a detector in some suitable circuit. A possible method of this type is illustrated in Fig. 3. Here the polarograph cell P is connected to a variable source of potential V, and a small resistor R is included in series with an electrode, in this instance the cathode.



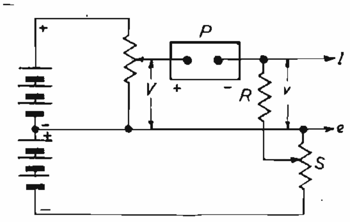


Fig. 3 (*left*). **Circuit enabling a cathode-ray tube to be used as a detector in polarographic measurements**

Fig. 4 (*right*). **Modified circuit in which correction is made for cell potential**

With any given applied voltage V, the changing current through the cell will set up a varying potential v across R which can be fed to an amplifier connected to the deflector plates of a cathode-ray tube. Thus the cathode-ray spot will be deflected by an amount dependent on the cell current so that pulses similar to those illustrated in Fig. 2 will be observed. From the oscillograph sensitivity and the value of R, the peak current may be found.

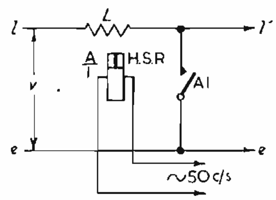
A disadvantage of this system is that the potential across the cell is never known exactly, for although V may be determined precisely, the cell potential is actually $(V - v)$ so that a correction is necessary. A modified circuit in which this correction can be made is illustrated in Fig. 4. Here the current indicating resistor R is not returned to the negative side of V directly, but to another variable potential source S which is of opposite sign to V, and which is in series with it.

If the potential between l and e (Fig. 4) is observed with a cathode-ray oscillograph, waveforms similar to those already described will be found. It is now possible, however, to adjust S so that for any given current through R, the potential between l and e is zero. At this current the cell potential is exactly V. The process of adjustment is to set up V at the required potential, while observing the current pulses on the oscillograph as drop follows drop. Then S is varied until at the current pulse peak the potential between e and l is momentarily zero. At other parts of the current pulse cycle the potential is not exactly V, but as no measurement is carried out there is no harm done.

Calibration of Oscillograph Unnecessary

This system at once makes calibration of the oscillograph unnecessary as it is enough to know R and the potential S to find the current from Ohm's law. The oscillograph must, however, be able to indicate zero input voltage to a high precision.

This latter condition can be achieved simply by adding the circuit shown in Fig. 5. Here the unknown potential



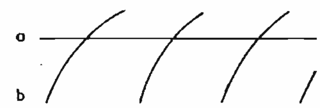


Fig. 5 (*left*). **Additional circuit enabling oscillograph to indicate zero input voltage to a high precision**

Fig. 6 (*right*). **Trace appearing on oscillograph—"a" corresponds to zero input voltage, "b" to the signal from the mercury electrode**

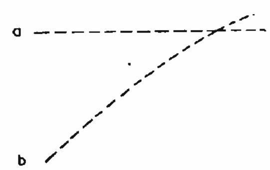
v is fed to the oscillograph amplifier via the leak resistor L which is high compared with R. The contacts of a high-speed relay are connected directly across the amplifier input and the relay is energized with 50c/s A.C. so that the contacts are closed for about 5msec 100 times a second. During the interval when the contacts are open, the unknown potential is fed to the amplifier, but when the contacts are closed the input potential is zero if the contact potential is low and the switch noise is small. The trace seen on the oscillograph is thus of the type illustrated in Fig. 6 in which two lines appear, the straight line "a" corresponding to zero input signal, and the curve "b" corresponding to the signal from the mercury electrode. This double trace is in reality built up of alternate periods (Fig. 7) as the switch opens and closes.

In this way the problem of providing a stable amplifier and zero marker on the oscillograph tube is avoided, as the zero signal mark is generated before being fed into the amplifier.

Method of Display

If the cathode-ray tube which is used for displaying the signals is given in addition a normal time-base deflexion at right-angles to the signal input, a trace rather like that shown in Fig. 6 can be produced.

The mercury drops fall at between 1 and 4 second inter-



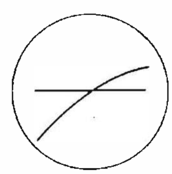


Fig. 7 (*left*). **Showing double trace built up by alternate periods as the switch opens and closes**

Fig. 8 (*right*). **Trace produced when using the mercury drops themselves to generate a slave time-base**

vals, and as these times are long, the adjustment of a trace of this kind is somewhat difficult. It seems that the eye, uncertain of the position of the maximum along the time axis, is unable to judge with accuracy the coincidence of the brief maximum with the zero line.

To make this easier, there are two possibilities. One is to dispense with the time-base altogether, when the trace is reduced to two points of light, one stationary and the other moving up and down, below, through, or above it. It is then necessary to adjust the current measuring potentiometer so that the moving spot just touches the stationary one at the limit of travel corresponding to the maximum current. (This can profitably be made to be the upper limit of motion to maintain the illusion of measuring a maximum). The maximum current at any cell voltage can then be read off directly from the potentiometer if it is suitably calibrated.

A rather better alternative to this is to use the mercury drops themselves to generate a slave time-base, applied to the tube as before, so that only one current curve is seen on the screen.

USE OF MERCURY DROPS TO GENERATE SLAVE TIME-BASE

It has been found that as each drop of mercury breaks away from the capillary tube a short pulse of about a quarter of a volt appears across the resistor R, and if this is amplified up it can be used to discharge a linear time-base circuit. This sweeps the cathode-ray spot across the screen once for each droplet formed, so that a trace like that shown in Fig. 8 is produced.

The end of such a trace is a well defined point to watch, and the eye has very little difficulty in judging the coincidence of the straight and curved line at the maximum, particularly when a cathode-ray tube with a long persistance screen is used.

With suitable values for the current resistor and the calibrated potentiometer, it is possible to measure currents

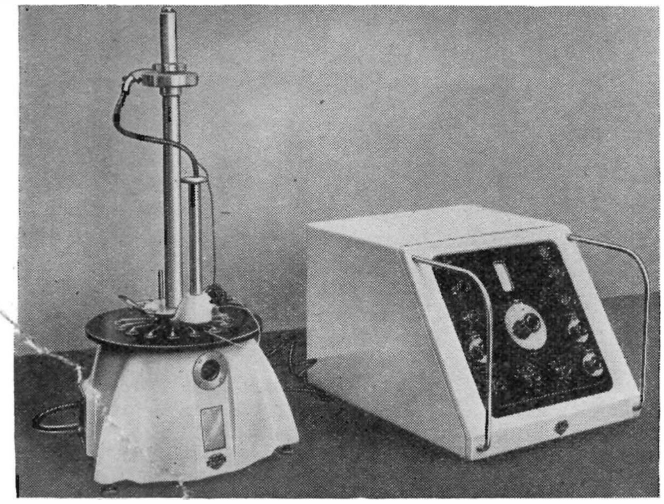


Fig. 9. The Mullard High Precision Polarograph

of about $100\mu A$ to an accuracy of $0.1\mu A$, differences of $0.01\mu A$ being visible.

STABLE SIGNAL LINE OR POINT NECESSARY

In all these displays it is important that the zero-signal line or point should remain steady, as otherwise the difficulty of adjustment is increased. During the life of each drop, the signal fed into the oscillograph amplifier varies over a wide range, and if a normal A.C. amplifier is used very long time-constant coupling circuits are necessary if the zero signal is to be preserved as a straight line.

This brings with it difficulties due to the long recovery time after accidental overloading, but if a D.C. amplifier is used, these difficulties all vanish and, apart from small thermal drifts, the proper presentation of the zero is preserved. It is convenient to arrange that, at the points at which the amplifier overloads on signals from the current resistor, the cathode-ray spot is still on the face of the tube so that the direction of misadjustment of the current potentiometer is obvious.

Conclusions

The first working polarograph built on the lines which have been described made possible the analysis of solutions of metallic ions to an accuracy of $\pm$ 0.3 per cent which compared favourably with the 1 per cent obtainable with existing commercial instruments. This instrument included refinements, which cannot be described here,[1] which made it particularly suitable for industrial work.

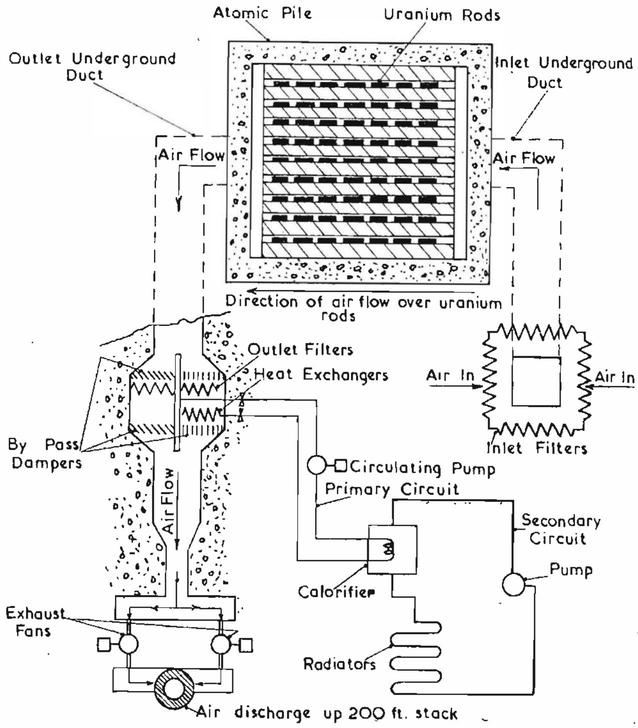
The final engineered version of the apparatus (Fig. 9) enables the current measurements to be made to a precision of 0.1 per cent in the usual working range. This promises a wider scope for polarographic analysis and serves to illustrate how the electronic instrument designer can assist the advancement of other sciences.

REFERENCE

C. H. R. GENTRY, G. NEWSON, *Metallurgia 41*, December (1949).

An Atomic Heating System

At the Ministry of Supply Atomic Research Establishment, Harwell, a building containing eighty offices now draws its heat direct from BEPO, the large experimental atom pile.



The atomic heating system

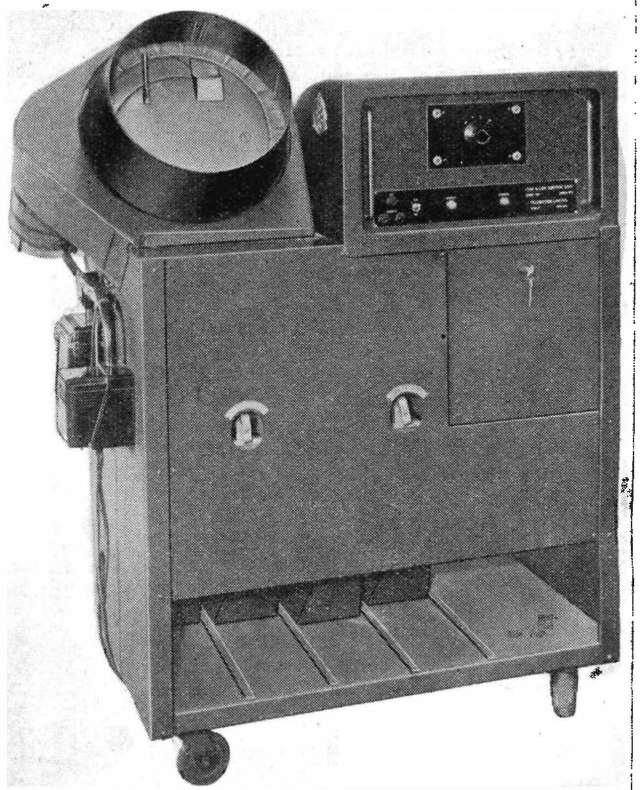
The constant hot water which flows through the pipes is obtained by placing a heat exchanger in the outlet air duct of the pile's air cooling system. Here there is a by-pass fitted with a damper which can be adjusted to vary the proportion of the air flow passing through the heat exchanger. Hot water from the exchanger is then circulated in a closed circuit by a small pump to a secondary water-to-water heat exchanger. This supplies hot water for space heating and domestic hot water supplies.

At present the air temperature at the primary heat exchanger is 135 degrees Fahrenheit, and the water itself is heated to 130 degrees. In 1952, when modifications to the pile have been completed, these temperatures will be substantially increased.

The installation was carried out by the Ministry of Works in collaboration with the Engineering Division, A.E.R.E. The heat exchanger, measuring 10ft by 10ft by 2ft 6in. weighs eight tons.

An Electronic Coin Sorting Machine

By R. W. Brierley *



The coin sorting machine

DURING 1947, the United Kingdom, certain Commonwealth countries and the Colonies commenced to issue cupro-nickel coinage and to withdraw from circulation those coins minted previously from alloys containing silver. When the silver content of the coins was changed, about the year 1925, a machine using an electro-magnetic principle was designed for automatically sorting coins of different alloys. The new alloy required a more sensitive machine and in 1949 the Royal Mint decided to attempt to develop this.

The experimental work that followed indicated that adequate discrimination between the two types of alloys could be achieved by a measurement of their relative conductivities, and a prototype equipment based upon this method was constructed in conjunction with the Royal Mint, London. Here, the development of the mechanical features was undertaken and in the accompanying illustrations will be seen the final form of the completed machine. Four of these equipments have been built so far.

In operation, the mixed coins are loaded into the rotary hopper which then feeds them, at discrete intervals, down a vertical chute. This chute guides the coins through the SENSING HEAD, which is a gapped, iron-cored inductance and the effect they have on the flux present in the gap is taken, in the main electronic unit, as an indication of their composition. Thus, if the flux variation is indicative of cupro-nickel, the coin is allowed to fall uninterrupted down the vertical guide and is then collected in the CUPRO-NICKEL receptacle. Silver coins, however, cause accurately-timed impulses to be fed to the EJECTOR unit which is mounted just below the SENSING HEAD and to the rear of the vertical chute. These impulses energize a small solenoid and an inclined deflector, attached to the plunger, is moved across the chute and into the path of the falling coins. Thus, when the coins strike this deflector, they are shot out of the vertical guide and are conveyed by an alternative shute to the SILVER receptacle.

Each machine will handle a range of denominations, it being necessary only to fit the correct size of guide to the hopper and to select the appropriate switch position on the front panel of the electronic unit. This latter operation brings into circuit one of a number of controls that have been adjusted previously for the various sizes of coin.

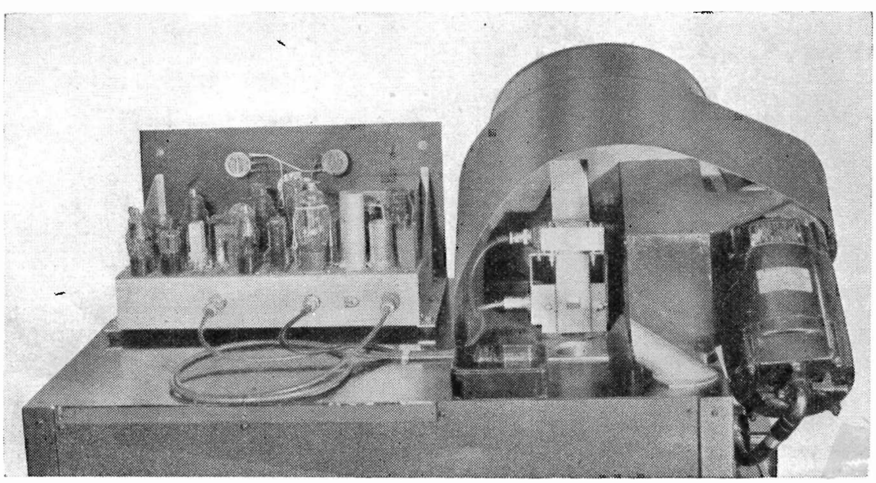
An automatic monitor is included in the main electronic unit and gives immediate warning to the operator in the event of a valve or circuit failure. Simultaneously, it disconnects the EJECTOR solenoid and so ensures that all coins pass now into the cupro-nickel container. The silver already sorted thus remains uncontaminated.

In view of the enormous number of coins involved in this sorting operation, much of the utility of a machine such as that just described would have been lost had it not been possible to achieve a high rate of sorting. Fortunately, this has not proved the case, and the present machines are capable of handling 8 coins per second or, over 150,000 coins per day. This appears adequate for present needs.

This note is published with the permission of the Superintendent, Royal Mint, London, and the Directors of Teledictor Limited, Dudley, in whose laboratory the electronic unit was developed.

* *Teledictor Ltd.*

A rear view with the covers removed. The sensing head and ejector unit can be seen on the vertical chute behind the rotary hopper.



A Self-Interpolating Crystal Calibrator

for Setting Up and Measuring Radio Frequencies

By D. Cooke

MODERN practice in radio communication and certain types of R.F. measurement demands a higher order of accuracy in frequency adjustment than conventional oscillators can normally give unless crystal controlled. When good accuracy and wide frequency coverage are both wanted, recourse is usually made to conventional variable oscillators aided by an external frequency meter or crystal calibrator for the final accurate frequency adjustment. The attendant procedure of referring to calibration charts or interpolating between crystal check points is difficult for an average operator and is at least a nuisance to a skilled operator, while to either it lays open the possibility of making mistakes.

It is the purpose of this article to describe a scheme* for frequency reference which combines the simplicity and convenience of a conventional crystal harmonic calibrator with an arrangement for automatic interpolation between the crystal check points and thus overcoming the principal shortcoming of crystal harmonic calibrators.

Basic Principle

A crystal oscillator of frequency f_C and its harmonics modulate a carrier wave generated by an oscillator, which will be called the interpolating oscillator, the frequency of which is continuously adjustable between f_i and $f_i + f_C$ where $f_i = nf_C$.

The components of the resultant modulated carrier wave comprise the carrier frequency, plus upper and lower sideband spectra, both of which have a similar form to that of the modulating waveform, i.e. crystal frequency and a family of harmonics. Fig. 1(a) is diagrammatic illustration of the frequency components in the output of the modulator (for simplicity only three sidebands are shown and the crystal frequency is assumed to be 100kc/s) comprising f_i (equal to a multiple of 100kc/s) and sidebands spaced $\pm$ 100, 200 and 300kc/s on either side of it. When, as in Fig. 1(b), the interpolating oscillator is moved by x kc/s to $f_i + x$ kc/s, each sideband also moves by x kc/s, and when, as in Fig. 1(c), the interpolating oscillator is further moved to $f_i + 100$, each sideband then occupies the position formerly occupied by its upper neighbour, having traversed the intervening gap. It follows that merely by tuning the interpolating oscillator by a small amount x (less than 100kc/s) a sideband can be made to appear at any frequency over the very much wider band covered by the sideband spectrum, and its frequency is $100m + x$ kc/s when m is an integer. The value of m is not indicated by the calibrator, but usually this figure will be obvious from the approximate frequency as given by the normal scale of the instrument with which the calibrator is being used.

To take a specific case, suppose the calibrator is required to cover a frequency band between 5,000 and 10,000kc/s. The interpolating oscillator would be arranged to function at about the middle of this band, say, over the range of 7,500 to 7,600kc/s and would be calibrated in terms of the sweep in frequency, i.e., 0-100kc/s. Harmonics up to the 25th of a 100kc/s crystal oscillator would be required for modulating the interpolating oscillator, so as to give a sideband spectrum extending over $\pm$ 2,500kc/s, i.e., 5,000-10,000kc/s. To generate a frequency at, say, 8,548kc/s, it is only necessary to turn the dial to figure "48", i.e., to adjust the interpolating oscillator to 7,548kc/s, upon which the sideband originally at 8,500kc/s moves to 8,548kc/s as required. Thus the interpolating dial always gives the last two digits of the frequency in kilocycles. The first two digits are, as explained above, derived from the rough calibration of the equipment whose exact frequency is being set up or measured.

The effective scale length over the frequency band covered by the calibrator is equal to that of the interpolating scale multiplied by the number of sidebands utilized. Thus a dial with a short simple scale for the interpolator gives the equivalent of a long elaborate scale for the whole frequency band. In the example quoted above the multiplying factor is 50, so that with an interpolating dial of, say, 4in. in diameter, i.e., about 6in. of scale length for 180° movement, the equivalent scale becomes 25ft.

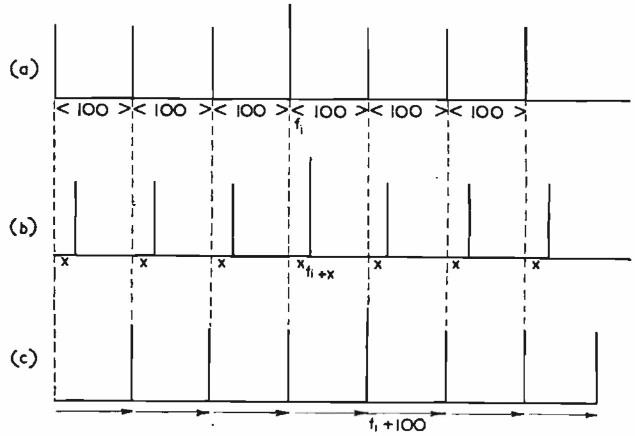


Fig. 1. The interpolating principle. Sideband spectrum when interpolating oscillator frequency is (a) f_i kc/s, (b) $f_i + x$ kc/s, (c) f_i + 100kc/s

Frequency Stability and Accuracy

A considerable improvement in frequency accuracy and in frequency stability can readily be attained compared with a conventional wide-range self oscillator. The interpolating oscillator at the beginning and end of its scale functions at crystal harmonic frequencies, therefore it can be checked for accuracy at these points against its own crystal and any relative error removed by an adjustment of a "set zero" control. Frequency stability can be better because of the smallness of the oscillator tuning band, from which it follows that the tuning component will be small in value and the bulk of the oscillator circuit will comprise fixed value components which can be high stability types; furthermore, temperature compensation can be precise and will remain effective over the whole operating range.

The overall accuracy of the instrument, assuming the crystal frequency to be correct, depends upon how well the interpolating scale is calibrated. The latter will be correct at its extremes, if the set zero control is adjusted properly, so that errors can only arise at intermediate points. Taking for example the case discussed earlier of a coverage between 5,000kc/s and 10,000kc/s with an interpolating range of 100kc/s, to maintain the error to less than 0.01 per cent at any frequency (exclusive of crystal error), the permitted dial calibration error is 500c/s, i.e., 0.5 per cent

* *British Patent No.* 544,959.

of scale length. This figure is well within the capabilities of quantity production technique, while if dials are individually calibrated, a much greater accuracy can be achieved.

Elimination of Spurious Responses

Depending upon the type of modulator and its linearity, various higher order modulation products which could cause spurious responses may be generated to a greater or less extent. These are a nuisance and must be avoided or reduced to insignificance. The dangerous ones are the lower sidebands of the interpolating oscillator second harmonic, and the upper harmonics of the crystal oscillator. The main precautions for eliminating them are first to design the interpolating oscillator and modulator such that the harmonic content is small, in particular the second harmonic, and second to ensure that the modulation waveform is optimum to give the requisite number of sidebands at good strength, yet at the same time have the least content of higher crystal harmonics.

To ensure that the harmonic content of the interpolating oscillation is small enough for practical purposes, it is sufficient to have a reasonably high Q for the oscillating circuit and to adjust the oscillator valve coupling such that oscillations are comparatively weak, conditions which can be fulfilled with relative ease on account of the narrow tuning range. A push-pull oscillator circuit would tend to reduce second harmonic still further, but is by no means necessary. Having taken steps to render the oscillator output adequately pure, care must be taken not to degrade it unduly in the modulator. A hexode modulator has been found satisfactory from this point of view. To achieve a good output of sidebands up to the highest one required, the modulator should be driven by the crystal oscillator so as to give a narrow pulse waveform in the output, i.e., hard Class C. The sideband output will then be high over a band equal to a little less than twice the reciprocal of modulating pulse width. The pulse should not be excessively narrow, however, otherwise high crystal harmonics may become a nuisance.

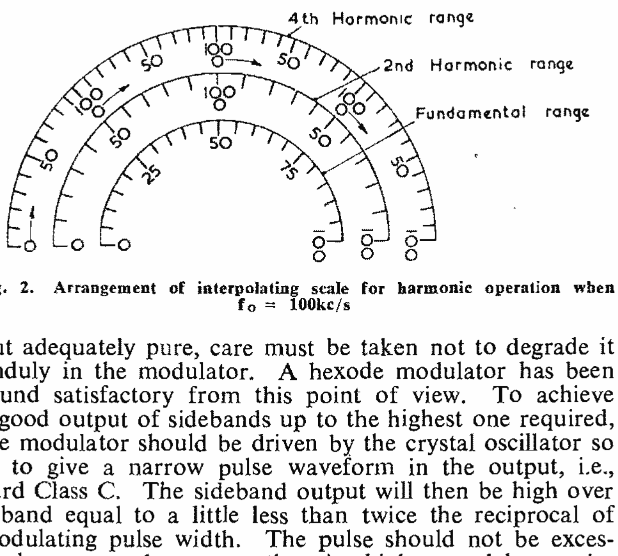


Fig. 2. Arrangement of interpolating scale for harmonic operation when f_0 = 100kc/s

A balanced modulator will very much reduce crystal harmonics in the output, but care is necessary to ensure a proper balance, if good performance is to be attained. Unless the utmost simplicity is called for, however, a balanced modulator is worth while.

The wanted frequency components in the modulator output can be readily distinguished from the unwanted components by their behaviour when the interpolating oscillator frequency is changed slightly. The wanted sidebands all shift in frequency in the same direction and by the same amount as the shift in interpolating frequency. The second harmonic sidebands, on the other hand, move twice as fast and the third harmonic sidebands at three times the speed, while the crystal harmonics are, of course, unaffected by the change in the interpolating oscillator. Thus by beating any component in the output with a fixed frequency and then shifting the frequency of the interpolating oscillator by a small amount, say 500c/s, all components, desired or undesired, can be identified by the amount of change in beat note. When designing a calibrator this procedure is extremely useful for adjusting the circuit parameters to remove spurious responses.

Frequency Coverage

The basic frequency range for which the calibrator is designed cannot be increased by working with its own harmonics, as can a conventional heterodyne frequency meter.

For wider coverages, some switching must be introduced to sub-divide the coverage. How this can best be done depends largely upon the particular purpose for which the calibrator is to be used and the frequency band to be covered, but nevertheless some general points can be made.

To simplify discussion a basic frequency coverage of 2 to 1 has so far been assumed. The coverage may be increased to about 4 to 1, however, without introducing switching, if the interpolating oscillator frequency is put rather towards the upper frequency limit, instead of at the centre of the band, so as to avoid trouble from second harmonic sidebands.

When the total coverage does not exceed a ratio of about 8/1, a simplified switching scheme is admissible. The range switch is required only to adjust the *LC* ratio of the interpolating oscillator such that the same tuning element and scale gives an equal frequency coverage for both sub-ranges. A small discrepancy shows up between the frequency scale laws for the two ranges, but the difference is so small as to be negligible for all except the very highest accuracy, and the single scale is adequate for most purposes. To cover for example, from 1Mc/s to 8Mc/s in interpolating sweeps of 100kc/s, the lower range would be arranged to cover from 1 to 4Mc/s with the oscillator tunable between 3.0 and 3.1Mc/s, while for the upper range of 4-8Mc/s, the oscillator would work from 6.0 to 6.1Mc/s, the crystal waveform being the same for both ranges.

For wider frequency coverages there is a further solution which is convenient for most types of equipment and preferable to having several switched sub-ranges. The circuitry is simpler and there is the advantage that the output is developed in the form of a single c.w. oscillation like an orthodox heterodyne wavemeter, instead of in the form of a multiplicity of sidebands. In this method a conventional heterodyne oscillator covering a frequency band of 2/1 is used in an auxiliary role either on its fundamental or, for higher frequency ranges, on one of its harmonics. The wide-range oscillator is first set precisely to the required frequency by means of a simple unswitched self-interpolating calibrator built into the same instrument, after which the calibrator is switched out of circuit. On its fundamental range the oscillator is then used as a conventional c.w. wavemeter. For higher ranges, harmonics are employed, the 2nd, 4th or 8th, etc., being enhanced and the others rejected, according to the range in use, by a circuit tuned with an additional gang on the oscillator tuning capacitor. Thus the wave-range switch is needed only for the purpose of changing the harmonic selector inductance according to the range in use, and to change the scale masks. In this way switching of frequency determining circuits is avoided with its ensuing deleterious effects upon frequency stability, while at the same time confusion from harmonics is eradicated. Furthermore all the digits of the frequency are read directly on the instrument, from the wide range and interpolating scales.

When using the c.w. oscillator on one of its harmonics the interpolating dial covers twice, four times, or eight times its normal frequency. Ambiguity in reading it can be avoided and the frequency digits be still given directly if the interpolating dial is calibrated appropriately, e.g., for the fourth harmonic range, the interpolating scale brought into use by the range switch would be divided into four sections side by side, each calibrated 0 to f_c. Fig. 2

showing a dial for a range of 8/1 should make this point clear.

Circuits

Fig. 3 shows a circuit for a calibrator in its simplest form, i.e., a combined oscillator and modulator without any range switching. A single triode-hexode valve is used, the triode section providing the crystal oscillator, while the hexode section functions as a combined oscillator and modulator. The tuned grid oscillator circuit $L_1C_1C_2$ is connected to the first grid of the hexode, while feedback is applied from the screen of the hexode acting as an anode via coil L_2. The modulated oscillation passes from the

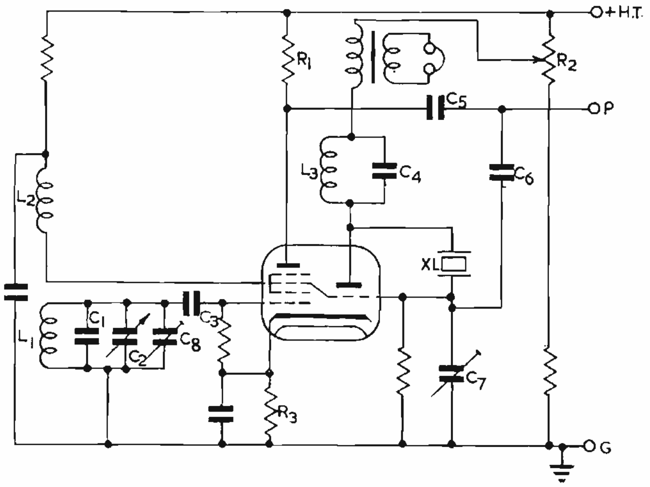


Fig. 3. Single-valve self-interpolating calibrator

anode of the hexode through resistance R_1 across which the output of the calibrator is developed and taken to terminal P through capacitor C_5.

C_3 and L_2 are adjusted so as to produce reliable oscillation of $L_2C_1C_2$, but with only a fairly small amplitude so as to guard against second harmonic content. The conditions of oscillation of the crystal are arranged to give the optimum amplitude for generation of the requisite harmonics by giving suitable values to its circuit parameters and fine control by adjustment of H.T. with R_2. Preset capacitor C_7 allows a small correction to be applied to the crystal frequency if necessary.

The listening point in the calibrator is in the anode circuit of the triode, outside signals being injected from terminal P to the grid of the triode via capacitor C_6. At this point may also be heard the beat notes between interpolating oscillator and crystal harmonics at the extremes of the interpolating scale. The set zero capacitor C_8 may by this means be adjusted to give zero audio beat at these points.

In this single valve circuit it is clear that crystal harmonics will be fairly prominent in the output. They may, however, be readily distinguished by their smaller amplitude and the fact that their frequency remains constant when the frequency of the interpolating oscillator is changed. It is worth while to take advantage of this useful fact by introducing a test button on the calibrator which when pressed produces a minute capacity change across the oscillator circuit and so a small change of the oscillator frequency. To check that an observed response is a wanted one, the button is pressed and if the beat note changes, all is well, if not a crystal harmonic is responsible.

The circuit of Fig. 3 will give the full accuracy of which the system is capable. Elaboration is not necessary or advantageous except perhaps to embody a balance modulator so as to depress crystal harmonics below the nuisance level.

Applications

Only few components, all of a readily available type, are used in the calibrator so that it can be made small and is relatively inexpensive compared with more conventional instruments of equivalent accuracy. These features suggest that the sphere of application is not limited only to an independent instrument for frequency measurement, but that consideration might be given to building it permanently into radio communication transmitters or laboratory instruments wherein accurate frequency alignment within a broad waveband is a useful facility. For example in a signal generator an inbuilt provision for precision frequency adjustment would be a useful feature for such purposes as measurement of overall receiver selectivity curves or for determinations of Q *in situ* from the width of the resonance curve at $\sqrt{1/2}$ peak response, etc.

In this paper consideration has been limited to the H.F. communication band, wherein there is a variety of applications, but the technique is basically applicable to other frequency bands.

Acknowledgment

Acknowledgment is made to the Chief Scientist, Ministry of Supply for permission to publish this paper.

Bombay Radio Exhibition

Postponement of Opening Date

The London Liaison Committee of the Radio and Electronics Society of India have issued the following announcement concerning the above Exhibition:—

"The General Council of the Radio and Electronics Society of India, organisers of the Bombay Exhibition, have decided to postpone the opening date of the Exhibition until November 1952. As previously announced, it had been planned to open on February 9, but according to the new programme the Exhibition will open on November 10 and close on November 30, 1952.

"Since the original plans were made there has been a serious development in the State of Bombay as the result of the failure of the monsoon. The Indian Government has been compelled to enforce a drastic cut in the supply of water and electricity and it is generally feared that the State will experience the worst famine for the last 50 years.

"In view of this development the members of the General Council of the Society have decided that it would be impracticable to hold the Exhibition in February when conditions are likely to be at their worst. It is also felt that this postponement will afford potential overseas exhibitors a better opportunity to prepare their exhibits and derive full benefit from the Show.

"The organisers of the Exhibition feel confident of a ready understanding on the part of overseas manufacturers and other exhibitors in view of the fact that the postponement is due to circumstances beyond their control. They therefore invite the continuation of bookings already established and the continued co-operation and support which they have enjoyed in no uncertain measure in sponsoring this venture.

"The London Liaison Committee will continue to provide an Information Centre for U.K. manufacturers and others interested in the Exhibition, and all inquiries should be in the first instance to the Committee's Secretary, Mr. B. A. Pettit, at 41, Kingsway, London, W.C.2."

A Simple Electro-mechanical Voltage Stabilizer

By J. V. P. Long *

THE voltage stabilizer to be described was built to provide an A.C. mains supply of 230 ± 0·5V from an input supply of 230 ± 30V. The instrument has a response time of 1-2 seconds and consequently does not smooth short duration fluctuations, but is effective for longer term drifts.

The apparatus consists essentially of an electronic circuit fed from the output of a Variac, the circuit being arranged to operate a reversible motor geared to the Variac.

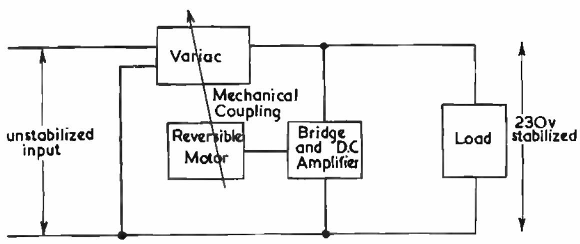


Fig. 1. The principle of the stabilizer

In this way mains fluctuations disturb the circuit from its balance position and cause the Variac to be rotated in the appropriate direction until balance is restored.

* *Department of Scientific and Industrial Research.*

A block diagram is shown in Fig. 1 and a detailed diagram in Fig. 2.

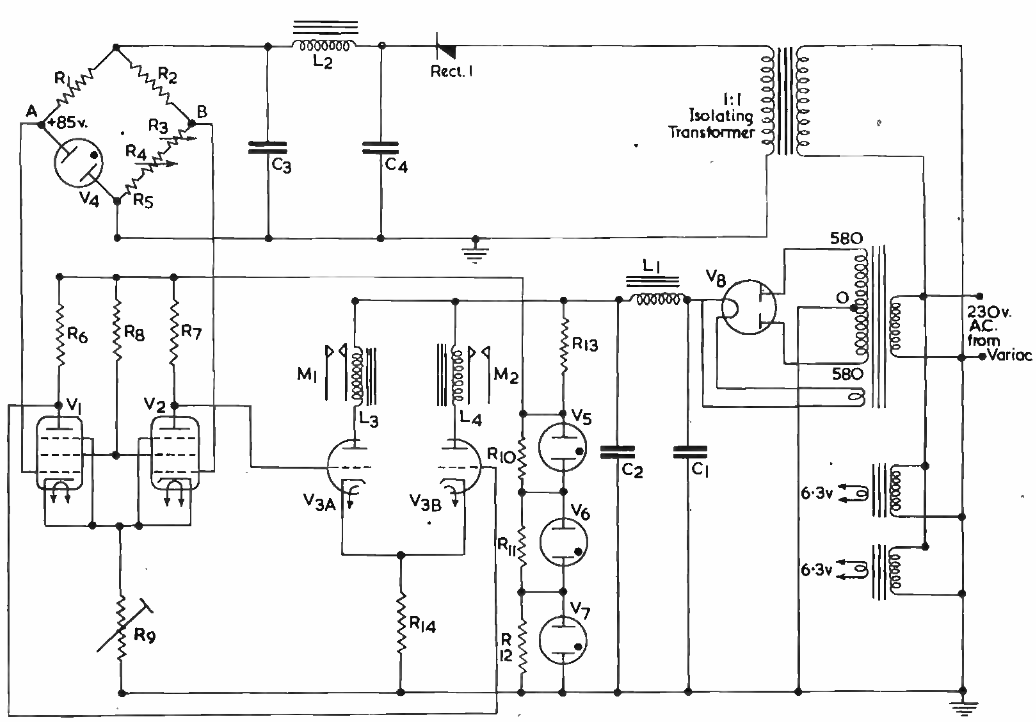
The circuit consists of a bridge network followed by a D.C. amplifier which operates relays controlling the reversible motor. The bridge contains an 85A1 voltage reference tube in one arm and is fed from the rectified mains supply. Consequently the potential of the point A will be constant while the potential of B will vary with the mains voltage. The points A and B are connected to the two grids of a "long tailed pair" (V_1 and V_2), the anodes of which are directly coupled to the grids of V_3. Both halves of V_3 are normally conducting, the contacts in the V_3 anode relays being open.

A drop in the mains supply causes the potential of the point B to fall, with the result that the anode voltage of V_1 drops and the anode voltage of V_2 rises. As a result of these changes the current in the relay L_4 falls and the contacts close. The relay L_3 remains energized with contacts open. The closing of the contacts of L_4 causes the motor to turn the Variac until balance is restored. A rise in mains voltage closes the contacts in L_3 and rotates the Variac in the opposite direction.

The potential of the cathodes of V_1 and V_2 is determined by the value of R_9 which is preset to give about -2 volts bias on the valves. The position of balance of

Fig. 2. Bridge and D.C. amplifier

$R_1 R_2$ 13k Ω R_3 500Ω R_4 5kΩ R_5, 15kΩ R_6 R_7 15kΩ R_8 15kΩ R_9 10kΩ R_{10} R_{11} R_{12} 1 MΩ R_{13} 5kΩ R_{14} 33kΩ C_1 C_2 8μF 700V C_3 C_4 8μF 350V L_1 10H L_2 10H L_3 L_4 12kΩ P.O. relays V_1 V_2 E.F.50 V_3 6SN7 V_4 85A1 V_5 V_6 V_7 VR150 V_8 5U4G Rect 1 300V 30Ma M_1, M_2 relay contacts to motor fields.



the bridge and hence the value of the stabilized voltage can be varied by means of R_3 and R_4.

The motor used to drive the Variac was a 24 volt antenna reel motor (obtained on the surplus market) fitted with internal gearing and clutch. A further gear reduction of 30 was fitted between the motor and Variac spindles in order to reduce the possibility of overrunning and hunting. The final Variac spindle speed was thus reduced to about 0.5 R.P.M.

The components used are in some cases not preferred types and in the interests of standardization these could be changed, e.g., 85A2 for 85A1, etc.

The limits to which the stabilizer will control the mains voltage are set by the smallest increment of voltage which can be obtained from the Variac. It is important in any controller of this type that the sensitivity of the amplifier should be below a certain value in order to avoid hunting. The amplifier sensitivity required can be calculated as follows. If v = smallest voltage increment of the Variac, s = sensitivity of the amplifier (voltage change from balance position required to close one or other relay) and x is the voltage change, then the relay will close if

$$s \leqslant x$$

Further, if

$$s < x < v - s$$

a balance is unobtainable.

Consequently the condition for balance is

$$s > v - s \text{ or } s > v/2$$

The apparatus has been in use in its present form for several months with a type 200 C.M.H. Variac and has provided stabilization to approximately ±0.5V.

Acknowledgments

The author would like to thank Mr. B. N. Audric and Mr. J. W. Bryant for assistance in constructing the apparatus described in this paper. The paper is published by permission of the Director of the Chemical Research Laboratory, Teddington.

An Optical Projection Comparator

By W. A. Gold, B.Sc. *

WITH the increasing complexity of modern electronic equipment it is becoming more and more customary to include, in the larger installations, built-in waveform monitors of the cathode-ray tube type. By means of permanent wiring and/or so-called "jumper leads" the

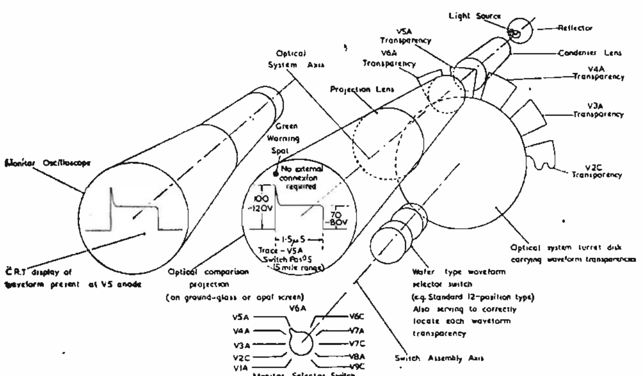


Fig. 1. The optical waveform comparator

waveforms at significant points in the equipment, when working under known conditions, may, for routine testing and trouble-shooting purposes be displayed and compared with the proper trace which should exist at the test point for correct operation of the apparatus.

The object of the optical projection waveform comparator shown in Fig. 1, is to facilitate such checking by simultaneously displaying for the operator the correct waveform at chosen points in the equipment under review on a ground-glass or opal screen placed in close juxtaposition to the monitor oscilloscope screen, so as to facilitate visual comparison of the traces.

Other essential data such as pulse duration and amplitude and whether or not manual linking of the monitor oscilloscope to the test point under consideration is required may also be included on each waveform transparency. Thus in Fig. 1 we see that the waveform at V_5 anode is being monitored in the test position illustrated, that the pulse length should be 1.5 microseconds with leading and trailing edges of the form shown and lying in amplitude between the voltage limits stated.

A green warning spot serves to emphasize the printed note saying that for this switch position no external connexion from the monitor oscilloscope to the test position under review is required, although this may sometimes be necessary. When that is the case, the appropriate transparency could carry a red warning spot emphasizing the instruction "EXTERNAL CONNEXION REQUIRED" to the operator.

The use of standard 16mm components in the projection system would appear to be advisable to secure good optical performance at the minimum cost.

It is hoped that this form of comparator will find increasing applications and utility in electronic equipments in the future, where its inherent simplicity would seem to commend its use for monitoring check purposes.

It must be emphasized, however, that the system calls for a high standard of reliability in the monitoring apparatus itself and in the associated wiring to the main equipment under observation. False indications of improper functioning due to monitor failures may thus be reduced to a negligible proportion of true operational faults.

* *Test Engineering Dept., A. C. Cossor Ltd.*

THE ENGINEERING CENTRE

The Engineering Centre, 351 Sauchiehall Street, Glasgow, C.2, has now opened a Catalogue Library which contains the literature of more than 3,000 firms, and also a complete set of British Standards. Frequent additions by the firms concerned, and constant supervision by their own technical staff, ensures that the library contains only the most recent publications.

The facilities offered by this valuable source of information are already being put to good use by consultants, designers, draughtsmen and buyers, as well as by the many overseas visitors who now include a visit to the Centre on their itineraries. It is doubtful whether there is another Catalogue Library in Great Britain which is so readily available to industry.

Manufacturers who have not included the Centre's name on their mailing lists for publicity matter are invited to do so.

On the Background of Pulse-Coded Computors

(Part 1)

By T. J. Rey,* M.A., B.Sc., A.M.I.E.E.

Calculating aids are shown to culminate in the computors dubbed "electronic brains", although they possess a mechanical ancestor. A short description of organization explains why they are useful in spite of the work they impose on humans. Subsequent sections deal with on-off signals and the physical embodiments of the mathematical concepts which are necessary for communication with and within the machine. Mathematical Logic and its connexions with ordinary arithmetic are introduced. Finally, "digital" and "analogue" systems are compared; the distinction turns out to be one of degree rather than of opposites.

THE mechanization of arithmetic goes back to the very beginnings of arithmetic. The fingers of the hands and the toes of the feet are the natural "digits". They are still used for counting by the young and the primitive as is the abacus, which was probably the earliest mechanical computing aid.

More advanced mechanization of addition and subtraction occurs in desk calculators, which operate on principles similar to those of the cash register. Multiplication and division are usually performed by repeated addition and subtraction respectively, and the numbers are set in by hand. Any numerical problem in mathematics may be solved with their aid, given enough time.

Lengthy problems can be solved rapidly with the "universal machines", of which more will be said presently. The mathematician must do the thinking; he must put the mathematical problem in algebraic form, choose the numerical data and plan the programme, i.e., the course of operations to be followed by the machine. In all cases, he must feed the machine initially, by giving it an input in the form of actual numbers.

If the machine is of the desk type, the mathematician must set up the machine afresh for every arithmetical operation. He must also check the results, intermediate as well as final. Again, if it is that sort of a problem, he must determine the next step on the strength of the result of the previous step, i.e., he must "discriminate". Problems requiring discrimination arise in applied mathematics, e.g., in the calculation of optical trajectories. Many others have been left in abeyance because computation by conventional means is too laborious. In these problems, a few data (including constants and tabulated functions) lead to a long sequence of arithmetical operations, possibly of the "trial and error" type. To cope with such problems expediently, a machine must possess both arithmetical and discriminating facilities; it must be able to receive the complete set of instructions (instead of being set up manually step by step) at the outset, as well as the numerical data; it must be able to hold intermediate results long enough, as well as to record the final answer. This is the concept of the modern "universal machine". It is in advance of all but the latest differential analyzers (V. Bush) and punched card methods (Hollerith) in as much as for scientific computation, the various units needed must have their inter-connexions changed manually for every new programme.

A "discriminating facility" is the provision for instructing the machine to compare a number just computed with another, and to select accordingly one out of two instructions available for the next step. This, together with provisions for searching (scanning) and for storing (memorizing) suggests to some minds that the "electronic brain" thinks. Others agree with Lady Lovelace[1] that "the machine is not a thinking being. It can do whatever we know how to order it to perform." Whether the term "electronic brain" is to be taken more literally than, say, the "electronic eye" is a stimulating question.[2,3,4,5]

The principal features of digital methods are beyond controversy, namely, flexibility, accuracy and (with electrification) speed, as will be shown below.

Electrical and Mechanical Machines

"The whole of the developments and operations of analysis are now capable of being executed by machinery".

Thus wrote Charles Babbage[1] who, over a century ago, conceived and partly built a universal computing machine, on purely mechanical lines, of course. The close mechanical tolerances required rendered the project too costly. This would still be true today, with the aggravation of comparatively low working speeds. The subject is fascinating even without its high speed feature, and so offers scope to the home constructor. Computor rules can be designed and tested with pen and paper alone, nor is the effort excessive if the only object is playing to win a simple game such as "Noughts and Crosses," "Fox and Geese" or "Nim".[6] Also small relay computors can be made cheaply.[7]

In the last decade, electro-mechanical (relay) and purely electrical (electronic) principles have come to the fore. The low accuracies required of the component parts do not impair the high speed and accuracy of overall performance. Hand-in-hand with the technical requirements of a bellicose globe, these points have stimulated study and construction. Special components, circuits and techniques are emerging. These are bound to find many applications, not only in numerical analysis by superseding mechanical methods and breaking fresh ground, but in statistics, accountancy, traffic control, etc. In some fields, computors are needed for a restricted class of problem, e.g., for X-ray analysis, or for just a single problem, e.g., for navigation. Such special purpose machines might be expected to be much simpler than a "universal," but the saving is likely to be one of size rather than of basic structure.

The present article is concerned with "digital" rather than with "analogue" computors, that is, with devices based on counting rather than on measurement; this distinction will be examined more fully in the final section.

* *E.M.I. Engineering Development, Ltd.*

Organization

All digital computing machines follow a similar strategy, as shown by a schematic of four constituent blocks or organs (Fig. 1).

Traffic may be in either direction between the organs.

"INPUT" is fed with so-called "words", of which there are two sorts: the numerical values (e.g., boundary conditions) of the problems and the constants (logs, trigonometric functions, etc.) likely to be needed; and the programme or set of instructions.

"OUTPUT" displays the answers, usually by actuating a tele-typewriter.

"ARITHMETIC ORGAN" provides the arithmetic operations $+$, $-$, $\div$, $\surd$, at most, and certain logical functions.

"MEMORY" or "STORE" is presented as a single block, but has at least three sections, corresponding to the blocks communicating with it. Extensive sections are devoted to hold the input information and, jointly with CONTROL, to mark the progress of the computation by counting. A small, fast-working section acts as a "work sheet" for the arithmetic organ.

"CONTROL" provides for the instructions to be obeyed, i.e. the desired operations to be performed on numbers in appropriate locations, in correct sequence. The distinction between this organ and the arithmetic organ is not hard and fast; the design may allow instruction words to be modified by the Arithmetic Organ so as to reduce the amount of storage and human preparation needed.

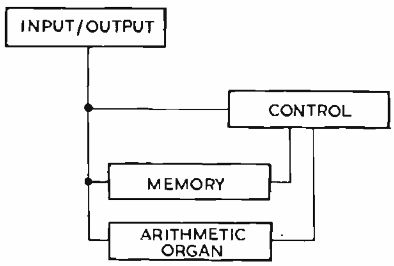


Fig. 1. Organization of computor

In order to follow the machine procedure, consider an addition such as $A + B = C$; also assume that the machine has had its programme inserted via input into the store, whence control has just provided it with the present instruction. This then transfers the contents of storage locations A and B to the arithmetic organ, causes them to be added and the sum to be transferred to storage location C. Finally, the present instruction enables its successor to be transferred from the store and to replace it in control. The final instructions specify the locations of the answers, transfer them to output for display and stop the machine.

The instruction word is of the "multi-address" type as it specifies two sources (A and B), a function ($+$), a destination (C) and the source of the next instruction. These components act on control and cause it to emit gating pulses to the appropriate circuits. For economy, the variety of functions is limited to a few dozen. Programming is thus a skilled task but an expert in numerical analysis has mastered the art within four hours.[8] The task of programming is reminiscent in turn of the organisation of a treasure hunt, of a time table and of a Meccano assembly. However, once a programme is made, it can be used repeatedly with different values of the parameters and possibly as part of a latter programme.

The most important aspect of programming concerns the repetitions which are inherent in most calculations. A chain of elementary operations is called a "sub-routine," as exemplified by the scalar product $\sum_{i=1}^{n} x_i y_i$.

Although it may be needed several times in one programme, a sub-routine is inserted only once and is linked-in again and again at the relevant points of the programme by means of the instructions.

The use of sub-routines suggests that there is a hierarchy of 'intelligence levels" which control a long and tedious computation, e.g. the frequency response of a filter,[9] by combinations of a very few instructions at each level.

The extent to which instructions must be coded into 'words' can be reduced, e.g. by the aid of windings on toroidal cores which may be plugged into the control panel.[9] In this case, the cores are labelled so that the addition $A + B = C$ is programmed by linking cores (A), ($+$), (B) and (C) with a single wire which acts as a primary winding for the four transformers. The pulse passing through the wire operates the internal circuits connected to the transformer secondaries.

Storage

Many different words (data, instructions, interim results) enter into a computation, but at any one step relatively few numbers are needed. Digits in current use are represented by electric pulses in an electrical computor. Low-pass filters (lumped or distributed) will delay pulses and, together with amplifiers for re-circulation, store them but they prove too expensive for large scale use. Electric pulses are supplemented by other physical quantities of an "on-off" nature.

The computor input is usually fed with data represented by holes in cards or tapes or as polarized spots on a magnetic wire or tape. The input organ has a "reading" section which changes the input signal to a pulse form for transmission to the internal store. In several successful computors, this store consists of large numbers of relays of the latch type.

To provide greater computing speed, which is largely governed by the maximum transmission speed of the internal store, Eccles-Jordan electronic trigger circuits were substituted for relays in the "ENIAC" computor which incorporates some 18,000 valves. The fact that an equipment containing so many valves continues to work for long periods justifies the computor designer's faith in valves operated in an "on-off" manner.

Apart from the recent magnetic trigger circuits,[10] three other principles have been developed to increase the speed and economy of the internal store. These are:

1. Delay Line
2. Magnetic Drum
3. Cathode-Ray Tube.

DELAY LINE

The finite speed of sound through a metal is used to provide a storage device. Quartz crystals are used to inject the signal at one end of the line and to receive it at the other. For example, a five foot column of mercury causes a delay of 1,024 microseconds, and allows 1,024 pulses to be stored at a 1Mc/s repetition rate using a 15Mc/s carrier.

MAGNETIC DRUM

The outstanding feature of the magnetic drum[12] is its compactness and low cost for a large storage capacity but the time required to obtain access to a given digit is long; an average of 10 milliseconds if the drum rotates at 3,000 R.P.M. In high-speed computors, the drum acts as a liaison between the external and the fast internal store.

CATHODE-RAY TUBES

In the cathode-ray tube store,[13,14] spots on an insulating screen are charged by secondary emission on the incidence of an electronic beam. Although this form of storage is essentially static, as is magnetic storage, the decay of charges by leakage must usually be offset by periodic regeneration, almost as in a dynamic store (delay line).

In all three cases, the storage medium is continuous, but is sub-divided into discrete portions by counters. Further apparatus is required to perform the change from and to electric pulses and to provide power amplification.

In almost every design, a modest number of electronic triggers is retained since they allow words to be set up ("staticized") or discharged ("dynamicized") at different rates and are invaluable for transfers between fast and slow stores.

The choice of the type or types of storage profoundly affects the design of the computor and determines whether parallel or serial methods must be used.

Parallel or Serial Mode?

The representation of a word is "parallel" if all digits are accessible at once, each at its own terminal; it is "serial" if all digits are accessible at the same terminal, at successive instants of time.

A serial word of p digits cannot be examined more quickly than in one minor-cycle (mC), the time taken by the digits to pass the same terminal. Circuits for arithmetical and other operations may then be used in time division multiplex, that is, serially. For example, two serial words are added by sending their digits to a single adding circuit pair after pair, the sum emerging serially. By contrast, parallel words are added on providing separate adding circuits, interconnected only for carry digits.

Other things being equal, comparison shows that the serial mode saves apparatus at the expense of time, but other things are not equal, and both modes have their supporters.

Briefly, the expense of time is not serious as pulse rates up to 5Mc/s are in use, hence serial computing speeds are ample for all but some super-colossal problems proposed by Neumann.[5] In fact, even the relatively modest speed of relay-type Universal Computors presents a problem. Several 10^5 Dollars are invested, and these must not lie idle while the next problem is being coded by the staff. The solution was suggested by C. Babbage[1]; instead of idling, the machine falls back on a stand-by programme of a highly repetitive character. Tomes of Bessel Functions (Harvard) and of precise data on the moon's movements for centuries ahead (I.B.M.) are coming out rapidly. On the other hand, equipment economy is limited by the need of more timing gear and staticizing means for the current instruction word, most of whose components must be obeyed simultaneously that is, in parallel form.

Hitherto, dynamic storage has been associated with the serial and static storage with the parallel mode. This practice is not beyond question since words in a static store may be serialized by means of trigger circuits. An assessment of the various possibilities is expected from experience with SEAC which is a particularly flexible computor.[16]

The Binary System of Numbers

The possibilities of representing numbers by pulses are best understood on first inspecting the familiar decimal notation.

For example, $365 = 3 \times 10^2 + 6 \times 10^1 + 5 \times 10^0$. There are two salient features:—

1. The symbol appearing in the r^{th} digital place to the left of the decimal point carries "weight" 10^{r-1}.
2. Every digital place is filled with one and only one of the ten symbols, 0, 1, .., 9.

The idea of a positional system in association with a power series is capital. It is unique in that it allows any integer to be written in terms of only ten different symbols and, more important still, it facilitates arithmetic. Without a positional system arithmetic would be stunted, as it was in ancient Rome and Greece where this idea was lacking. The use of many special symbols was not of much help.

The choice of ten as the base or radix is not, however, very important. It is a natural radix because vertebrates are normally born with ten fingers. It is equally natural for an electrical switching device to have a choice of only two states. Contacts are either closed or open, valves either conduct or do not and, in this way, a current tolerance of 50 per cent is permissible; these devices may then be used to indicate either 1 or 0. This leads to the binary system,* a number system with the base two.

In binary notation, the decimal number 365 is expressed as 101101101.

The binary notation is longer than the decimal, the average being $\log_2 10 \approx 3{\cdot}3$ times as long. This is offset by the simplicity of digital symbols, of which there are only two, 0 and 1.

To take a small binary number, thus

$$1101 = 1 \times 2^3 + 1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$$
$$= 8 + 4 + 0 + 1 = 13 \text{ in decimal notation.}$$

Thus in the binary system, numbers are built up so that

1. The symbol appearing in the r^{th} digital place to the left of the binary point carries weight 2^{r-1};
2. Every digital place can be filled with one and only one of the two symbols 0, 1. (C. Shannon has contracted the words "binary digit" to "bit.")

"On-off" devices do not compel sole use of the binary system. For instance, each decimal digit may be represented by four bits; the decimal expression 365 is then represented as the word 0011 0110 0101.

Again, mixed radices may be employed; e.g., in the bi-quinary system as used in certain relay computors, each decimal digit is allotted seven binary places. For instance:

$3 = 0 + 3$ is shown as 01 01000,

$7 = 5 + 2$ is shown as 10 00100;

the first two bits indicate 0×5 or 1×5, the other five just one of the five symbols 0, 1, .., 4. The decimal 73 then appears as the word 10 00100 01 01000.

It will be noticed that any decimal digit, including 0, is represented by two "ones" and five "noughts"; the fact is applied in relay computors on arranging alarm circuits across auxiliary contacts to stop the machine whenever other than two out of seven relays (one in each sub-group) are closed; this is very effective as a check on the transient contact troubles typical of electro-mechanical relays.

Both these mixed systems simplify conversion between decimal notation and binary words, a necessity unless the human computor can learn to think entirely in the latter. This is not so where the computing machine forms a link in a chain of devices and the neighbouring links have binary scale output and input, respectively. However, these conversions can be programmed as sub-routines; also such departures from the binary system complicate the arithmetic organ, waste time and storage (as will be seen from the examples), and are not accepted in the majority of high-speed designs.

The Largest Number

It is easy to show that there is no largest natural number: for supposing $(M - 1)$ be claimed to be the largest, addition of unity yields M, which is certainly larger than $(M - 1)$. But if M is too big this sum cannot be done in our heads. Similarly, the internal store of the machine is finite. Turing[7] has shown how an external supply of tape extends the "memory"; but the internal store must be relied on for fast work. It can have only a finite number of different states, $M - 1$ say; hence there is a number $(M - 1)$ which it can just represent, and it cannot truly represent M, $(M + 1)$, etc., there being no states corresponding to numbers $> (M - 1)$. M may take different values in different sections of the same machine, or there may be provision for self-adjusting scale factors

* *This system is common for fractions of the inch: $\frac{1}{2}$in., $\frac{1}{4}$in., . . . $^1/_{128}$in. etc.*

(sliding n-ary point). Neither possibility invalidates the argument.

Accordingly, machines represent numbers "Congruent modulo M" only; if the number n is indicated, it may really stand for another number n', such that n and n' are congruent with regard to the modulus M; this is written

$$n' = n \pmod{M},$$

and signifies that there is an integer k such that

$$n' = n + k.M.$$

Examples

$$9 = 2 \pmod 7 \text{ since } 9 = 2 + 1 \times 7;$$

$$4 = 1 \pmod 3,\ 316 = 1 \pmod 9, \text{ etc.}$$

Congruences apply to negative numbers also:

$$-9 = 5 \pmod 7 \text{ since } -9 = 5 - 2 \times 7.$$

$$-4 = 2 \pmod 3,\ -316 = 8 \pmod 9, \text{ etc.}$$

This Gaussian congruence is met with in daily life; the hands of a clock read the time congruent modulo 12 hours, and car mileage is indicated (mod 10^5 miles) by a counter – if not disturbed.

The geometric representation of real numbers on a line is familiar, (Fig. 2).

Congruent numbers are represented better on a circle. (The modulus = 6 in Fig. 3).

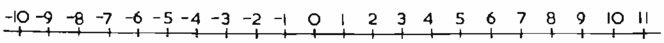
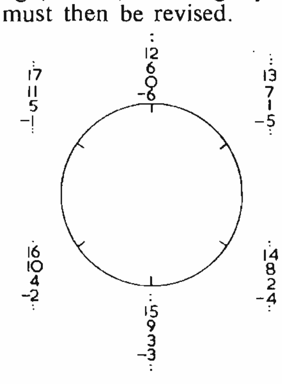


Fig. 2. Line of real numbers

Congruences with regard to the same modulus may be added, subtracted and multiplied; hence where there is no danger of ambiguity, congruences may be written as ordinary equalities.

Returning to computors, the limitation to a fixed number of states imposes on the mathematician a detailed preliminary investigation of the future run; only then can the problem be prepared so that $(M - 1)$ will not be exceeded falsely at any stage; initial, intermediate or final. Clearly ambiguities by an integral (non-zero) multiple of the modulus M cannot be tolerated (excepting problems in congruences). In fact, the "electronic brain" not only fails to "think" about these things, it must be spoon-fed. Of course, the machine can be (and in the B.T.L. types, is) made to stop and ring an alarm when, in certain locations, there are numbers exceeding $(M - 1)$ or a slightly smaller number; the scale factors must then be revised.

Fig. 3. Circle of congruent numbers



Means for dealing with the end carry digit have to be provided for, even if the numbers are small enough, operations can yield numbers which are greater than M by way of a carry digit from the highest digital place available. Now since

$$M = 0 \pmod M,$$

C.S. (carry suppression) at the end is both justified and necessary in addition and in signed multiplication. A slight variation of the end C.S. method will be discussed later.

Signed Numbers

For the purpose of arithmetic, it is practically essential to represent both positive and negative numbers by pulses of the same polarity.

The customary representation by absolute (positive) magnitude and separate sign can be instrumented. The sign needs one bit, e.g., "0" for "+" and "1" for "–". Multiplication is then a straightforward operation. However, difficulty is experienced with addition or subtraction since, with unlike signs, the addends must be compared to determine which has the larger magnitude before the summation can commence.

Addition is the commonest arithmetical process, hence signed magnitudes are not used for it. However, in one computor,[18] they are used for multiplication, but are transformed to the "complements code" for addition.

The complements code is an application of congruences. It is widely used in all types of digital computors. In any code of this nature, the machine can register numbers which appear to be positive only; but these coded numbers or "words" represent other numbers, positive or negative.

With $(M - 1)$ as the largest coded word represented in the machine, let n_A be the coded word which represents the actual number A.

The complements code then implies that

$$n_A = A \text{ if } A \text{ is positive, but that}$$

$$n_A = M + A \text{ if } A \text{ is negative.}$$

Thus, positive numbers are coded into themselves, but negative numbers are coded into their complements with regard to the modulus M. It is necessary to restrict the magnitudes of the actual numbers to avoid overlapping.

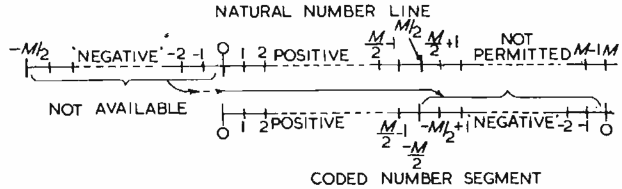


Fig. 4. Illustration of complements code

Assuming that M is an even number, then for A positive,

$$0 \leq A = n_A \leq M/2 - 1,$$

for A negative

$$-M/2 \leq A \leq -1, \text{ i.e., } M/2 \leq n_A \leq M - 1.$$

This coding amounts to a mapping of the actual number line on to the coded number line; by taking complements, the segment of actual negative numbers is shifted by an amount $+M$ into the positive part of the code-word line. (Fig. 4).

The smallest negative number $A = -1$ is coded into the largest word available, $n_A = M - 1$; the largest negative number $A = -M/2$ is coded into $n_A = M/2$.

Example

Let $M = 100$, then $n_5 = 05$, $n_{-5} = 100 - 5 = 95$. The integers from -50 to $+49$ inclusive can, in this case, be represented.

Addition is very simple, subject only to the condition that A, B and $A + B$ are restricted as above; this is obvious if A and B are both positive. If one is negative, say A, then

$$n_A = M + A = M - |A|, \text{ so}$$

$$n_A + n_B = M - |A| + |B|;$$

if $B < |A|$, no end carry arises and the word sum represents the negative number $(A + B)$;

if $B \geqslant |A|$, an end carry is generated but suppressed; the positive number $(A + B)$ corresponds to the sum of the words.

The sum also works out correctly, if both A and B are negative, so that in all cases of addition

$$n_A + n_B = n_{(A+B)}.$$

Thus, the code admits of the ordinary laws of addition, i.e., the sum of two code words is the code word of the sum of the numbers represented originally. This is subject only to the above numerical restriction on the magnitudes of the numbers, and to suppression of the carry from the highest place.

Signed addition facilities obviously admit of subtraction; this also follows the ordinary laws although coded words are substituted for signed numbers.

Thus, since $(A - B) = A + (-B)$,

$$n_{A-B} = n_A + n_{-B}.$$

Now, if B is positive, $n_{-B} = M - |B|$, and

if B is negative, $n_{-B} = -B = |B|$, so since $|B| = (|B| + M) \pmod M$, then in each case $n_{-B} = n_{M-B}$

$$= M - n_B.$$

Hence

$$n_{A-B} = n_A + n_{M-B}.$$

Taking complements with regard to M may involve carries, except with regard to a string of nines (decimal system), e.g.

$$\begin{aligned} n_{-300} &= 10^4 - 300 \\ &= (10^4 - 1) - 300 + 1 \\ &= 9 \times 10^3 + (9 - 3) \times 10^2 + 9 \times 10^1 \\ &\qquad + 9 \times 10^0 + 1 \\ &= 9699 + 1 \\ &= 9700 \end{aligned}$$

Two " nine " carries arise in the last step, on adding the " fugitive " digit 1; if this is omitted, carries cannot occur in forming complements. In the example the complement 9699 would obtain, i.e., with respect to $10^4 - 1$. If this procedure is adopted, the fugitive digit has to be restored on certain occasions. Thus, adding a negative number to a larger positive number would yield a positive sum, in error by unity; in the example.

$$n_{582} + n_{-300} = \begin{array}{r} 0582 \\ +9699 \end{array} = 1)0281,$$

where 1) indicates the end carry. On taking the end-carry round to the lowest digital place, and adding it, the desired correction obtains:

$$1)\ 0281 = 0281 + 1 = 0282$$

The end-around-carry method renders carries less frequent; it is commonly used in mechanical calculators where carries are troublesome.

Multiplication is more problematical, for it is only if both A and B are positive that

$$n_A \times n_B = n_{(A \times B)}.$$

If A is negative and B is positive, then

$$n_A n_B = (M + A)B = MB + AB,$$

whereas the product AB,* a negative number, should be coded as

$$n_{AB} = M^2 + AB,$$

which may be written

$$\begin{aligned} n_{AB} &= n_A n_B + M(M - B) \text{ and, on coding } (M - B), \\ &= n_A n_B + M\, n_{M-B} \\ &= n_A n_B + M(M - n_B). \end{aligned}$$

Similarly, if both A and B are negative, the product of the code words must be corrected by adding in $M(M - n_B) + M(M - n_A)$.

The correction terms are complements of the coded words, multiplied by M; the last step is merely a shift to the left; e.g., in a decimal computor with $M = 10^6$, the complements would be shifted 6 places to the left.

Decoding also requires discrimination:

if $n_A < M/2$, then $A = n_A$, but

if $n_A \geqslant M/2$, then $A = n_A - M$.

Conditional use of the complements in multiplication and decoding means discrimination, and so slows down and complicates these frequent operations. A remedy is available in the case of the binary scale, by a device to be described next.

* *Note that the product AB may have nearly twice as many digits as either A or B; hence n_{AB} is taken as a double length word, with modulus M^2.*

The Complements Code in the Binary System

Sign representation is simplified in the case of the binary system.

Let the coded words be numbers to p binary places, with the binary point to the extreme right:

(1) $n_A = a_p \times 2^{p-1} + a_{p-1} \times 2^{p-2} + \ldots + a_1 \times 2^0$, where the symbols

$$a_r = 0 \text{ or } 1,\ r = 1 \text{ to } p.$$

The modulus is then $M = 2^p$ and, in the code, complements are taken with regard to 2^p. The numbers represented by the word are confined to lie in the closed interval $(-2^{p-1}, +2^{p-1} - 1)$.

Let A be any number in this interval. Then by the convention of the code, it may be written,

(2) $A = n_A - a_p \times 2^p$,
for if A is positive, $a_p = 0$, $A = n_A$,
and if A is negative, $a_p = 1$, $A = n_A - 2^p$.

Combining (1) and (2),

$$A = -a_p \times 2^p + a_p \times 2^{p-1} + \sum_{r=1}^{p-1} a_r 2^{r-1}$$

$$= a_p 2^{p-1}(-2+1) + \sum_{r=1}^{p-1} a_r 2^{r-1}, \qquad \text{hence}$$

(3) $A = -a_p 2^{p-1} + \sum_{r=1}^{p-1} a_r 2^{r-1}.$

It should be noted that the right-hand sides of Equations (1) and (3) differ only in the sign of the first term. But, in the code

$$-2^{p-1} = 2^p - 2^{p-1}, \text{ i.e., } -2^{p-1} = 2^{p-1} \pmod{2^p}.$$

Hence, it is natural to take the weight of the last digital place negative, i.e., as (-2^{p-1}) and not as 2^{p-1}. With this interpretation, the right-hand sides of Equations (1) and (3) become identical; this must also be true for the left-hand sides, i.e.,

(4) $A = n_A$

for both positive and negative values of A; thus, the actual number and the coded number have the same value in this interpretation.

Accordingly, systems of multiplication and of division with simple unconditional correction for signs may be devised. Coding and other operations are also simplified.

(To be continued)

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The Prediction of Audio-Frequency Response

No. 2—Circuits with Two Reactance Elements (Part 2)

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

Slope Transition Case

As stated in the first part of this data sheet, negative values of E in Equation (4) or (6), according to whether the circuit is of the high or low frequency cut-off type respectively, result in a form of amplitude response that can be regarded as passing through a transition from a characteristic having an ultimate slope of 6db/octave to one where the slope is 12db/octave. The transition frequency can be found from a modified form of Equations (3) or (5). For the high frequency cut-off networks,

$$\omega_i^2 = \frac{1}{L_s C_p}\left[\frac{L_s}{2C_pR^2} + \frac{C_pr^2}{2L_s} - 1\right] \text{ or}$$

$$\omega_i^2 = \frac{-E}{L_s C_p} \quad \ldots\ldots\ldots\ldots \text{(3b)}$$

while for low frequency cut-off networks,

$$1/\omega_i^2 = L_pC_s\left[\frac{r^2C_s}{2L_p} + \frac{L_p}{2R^2C_s} - 1\right] \text{ or}$$

$$1/\omega_i^2 = -E\,.\,L_pC_s \quad \ldots\ldots\ldots\ldots \text{(5b)}$$

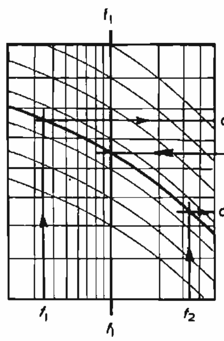

Fig. 4. Illustrating the use of Chart 6

To obtain the response in these cases, the value of E obtained from Equations (4) or (6) is substituted in the modulus of the attenuation coefficient, and to render the response characteristic dimensionless, x is written for ω/ω_i in high frequency cut-off characteristics, and for ω_i/ω in low frequency cut-off characteristics. This produces a general form, giving the amplitude response in db,

$$\text{db loss} = 10\log_{10}\left[1 + \left(\frac{E}{1 + r/R}\right)^2 (x^4 + 2x^2)\right] \quad \ldots\ldots\ldots\ldots \text{(17)}$$

Substituting $x = 1$ gives the attenuation at the transition frequency,

$$\text{db at } f_i = 10\log_{10}\left[1 + 3\left(\frac{E}{1 + r/R}\right)^2\right] \ldots\ldots \text{(18)}$$

Use of Charts 5-8

Chart 5 serves a purpose for the transition case similar to that served for the peaking case by Chart 1. The method of reference is self-evident. Chart 6 gives a series of response curves for values of db at f_i between ·01 and 20. The reference frequency is f_i, and the appropriate curve is selected by finding the one whose loss at f_i coincides with the value found by Chart 5. The frequency reference at the bottom is for high frequency cut-off networks, and this reference forms the basis for the chart, as most applications for this chart will be for high frequency cut-off networks. There is a conversion reciprocal scale to suit low frequency cut-off networks at the top of the chart. Fig. 4 will clarify the use of Chart 6.

Charts 7 and 8 give the phase response for all cases bebetween a peaking case giving 30db peak and a transition case having a loss at f_i of 20db, that is, corresponding to the amplitude cases given by Charts 1 to 6. Chart 7 converts relative frequency (the reference frequency being related to

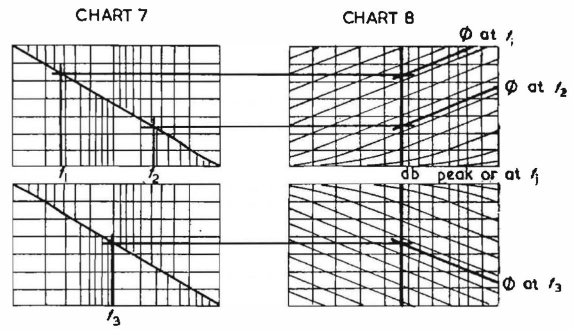

Fig. 5. Illustrating the use of Charts 7 and 8

the amplitude reference by Equation (9) or (10) and given by Chart 1 or 5 on the auxiliary scale) for either the high or low frequency cut-off network into arbitrary reference units for Chart 8. Fig. 5 shows how these two charts are used together.

Charts 5 & 6

Example 5.

A valve of A.C. resistance 50kΩ is coupled to the following stage by means of choke capacitance coupling. Choke 130H; Coupling capacitor 0·02μF; Grid leak 0·25MΩ.

(Continued on p. 38)

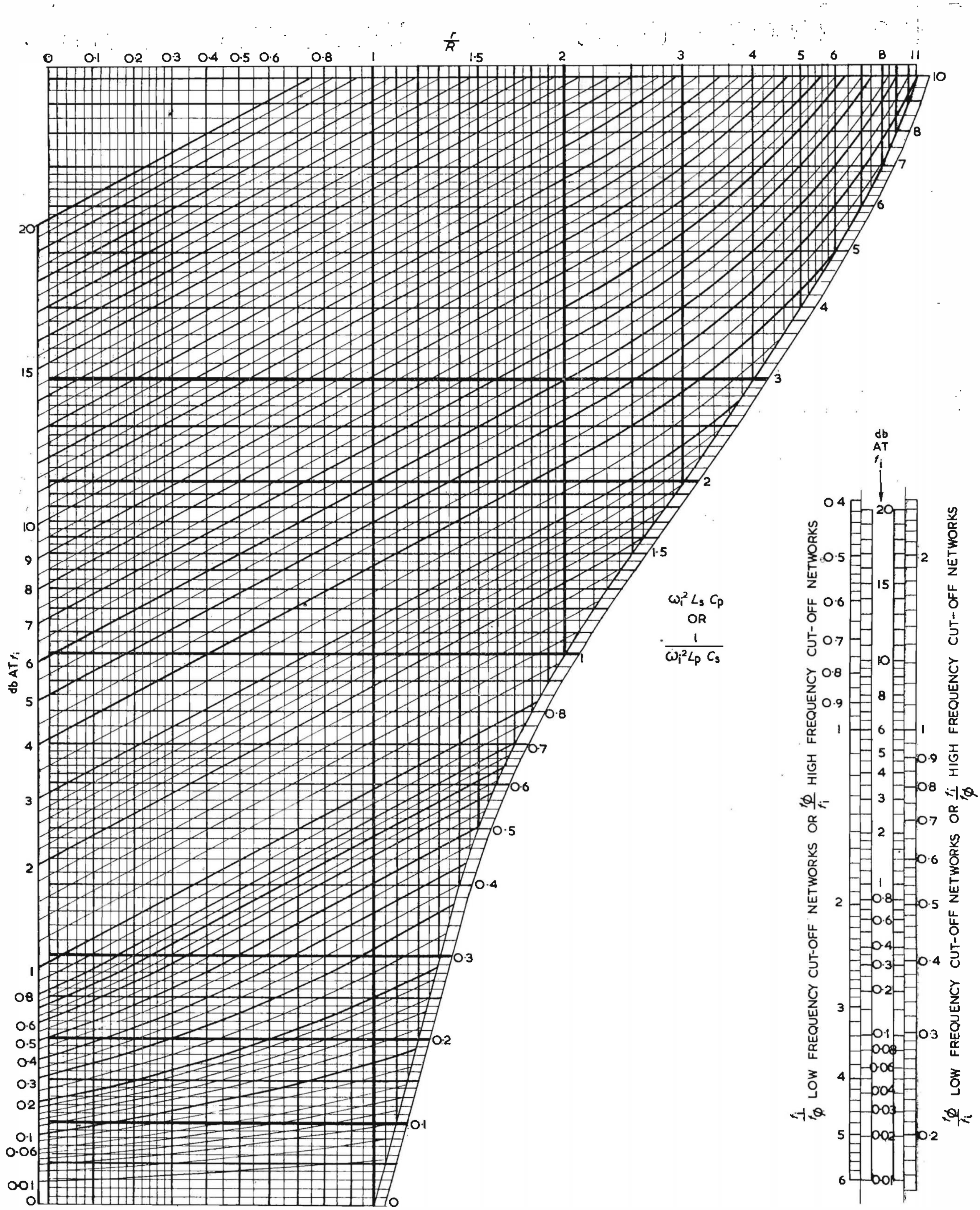

Chart 5. Attenuation of transition frequency

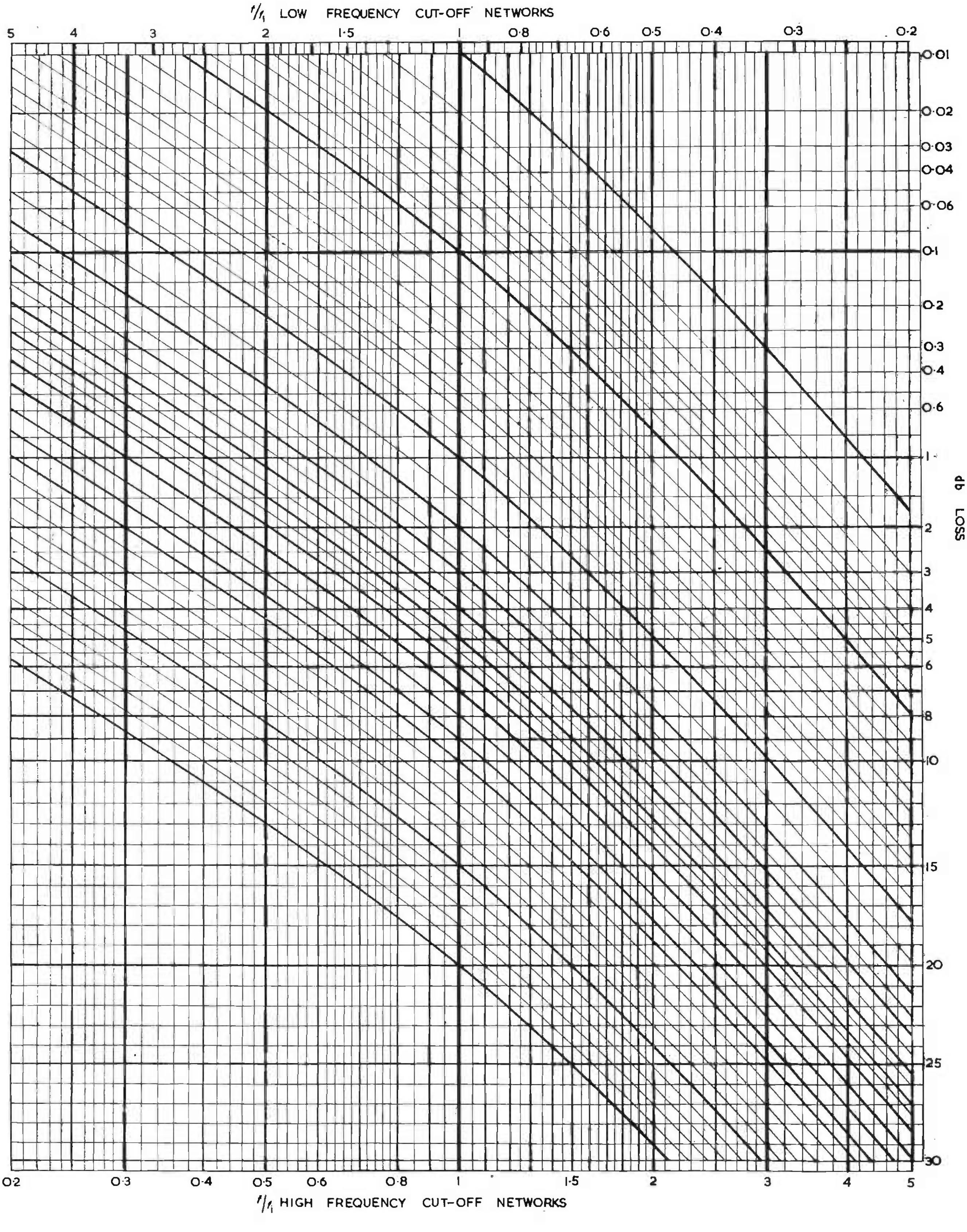

Chart 6. Transition slope response curves

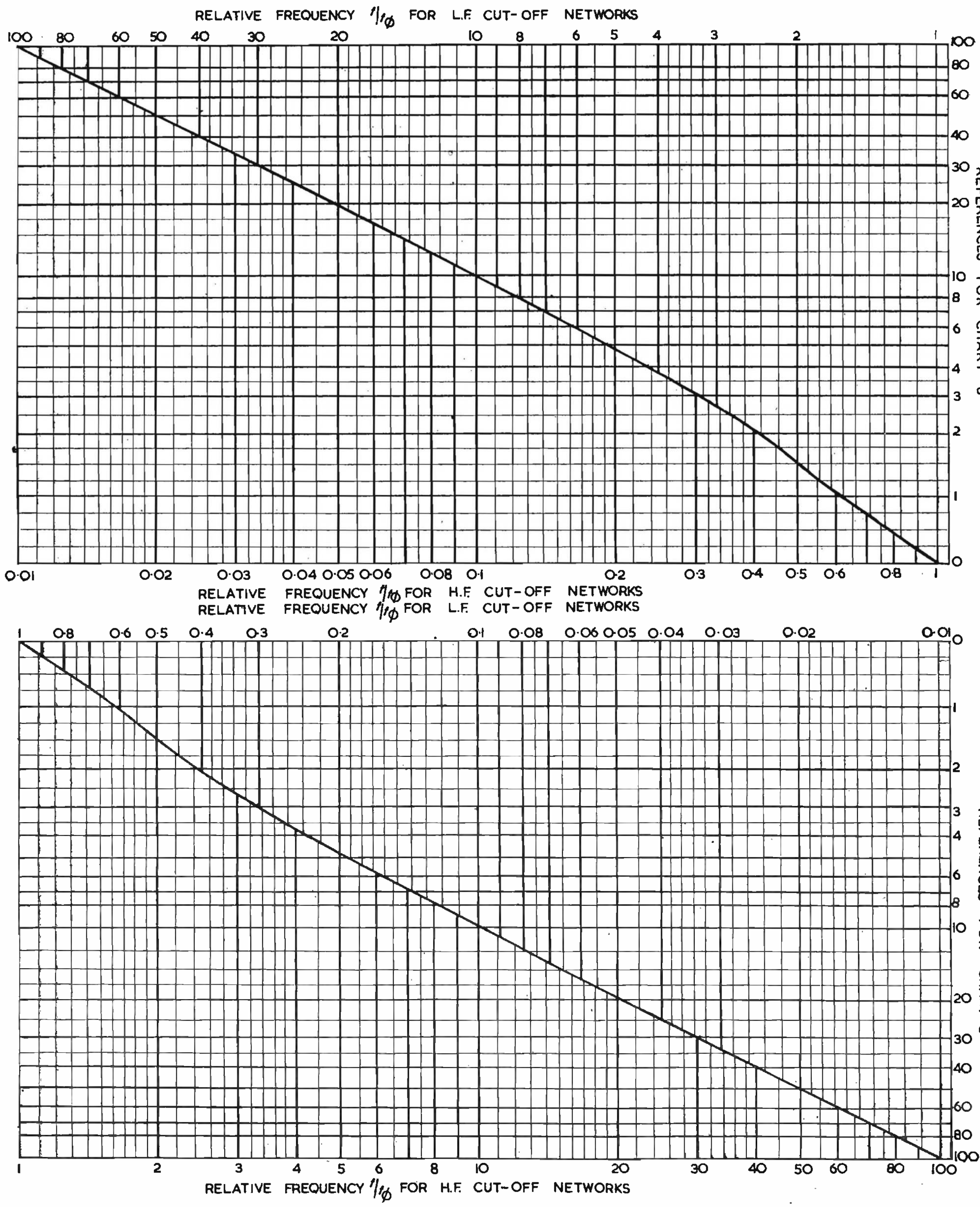

Chart 7. Universal phase response

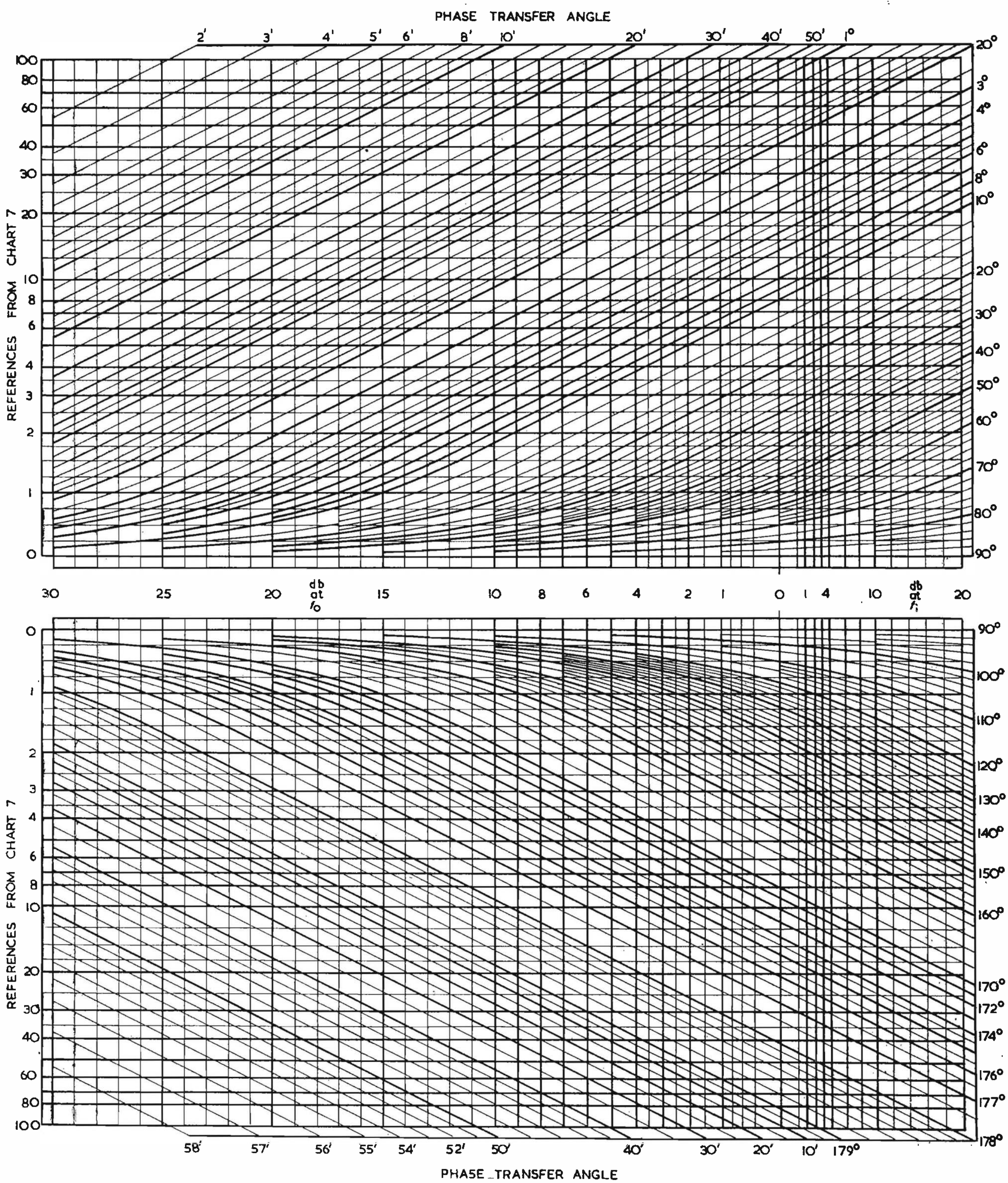

Chart 8. Phase reference for Chart 7

This employs the circuit of Fig. 2(b), in which $r = 0{\cdot}25\text{M}\Omega$ and $R = 50\text{k}\Omega$. Evaluating,

$$\frac{r^2C_s}{2L_p} = \frac{6{\cdot}25 \times 10^{10} \times 2 \times 10^{-8}}{2 \times 130} = 4{\cdot}8;$$

$$\frac{L_p}{2R^2C_s} = \frac{130}{2 \times 2{\cdot}5 \times 10^9 \times 2 \times 10^{-8}} = 1{\cdot}3;$$

$$\frac{1}{\omega_i^2 L_p C_s} = 4{\cdot}8 + 1{\cdot}3 - 1 = 5{\cdot}1; \quad r/R = \frac{2{\cdot}5 \times 10^5}{5 \times 10^4} = 5.$$

Applying these values to Chart 5, the db at f_i is found to be 5db. Reference to the auxiliary scales on Chart 5 shows that $f_\phi / f_i = 0{\cdot}925$. This is the relation between the reference frequencies used for Charts 6 and 7 in this case. Referring to Chart 6, it is found that for relative frequencies as tabulated below, the corresponding db losses are given:

f/fi ..	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
db loss	27	20.4	16	12.7	10.3	8.4	7	5.85	5
f/fi ..	1.5	2	2.5	3	3.5	4	4.5	5	
db loss	2.5	1.48	0.98	0.68	0.5	0.39	0.31	0.25	

Example 6.

A redesign of the circuit of Example 3 results in a primary self-capacitance of 2,500pF, and a leakage inductance of 77.5mH, $r = 10^4$, $R = 10^5$ as before.

$$\frac{L_s}{2C_pR^2} = \frac{7{\cdot}75 \times 10^{-2}}{2 \times 2{\cdot}5 \times 10^{-9} \times 10^{10}} = {\cdot}00155$$

$$\frac{C_pr^2}{2L_s} = \frac{2{\cdot}5 \times 10^{-9} \times 10^8}{2 \times 7.75 \times 10^{-2}} = 1{\cdot}612,$$

$$\omega_i^2 L_s C_p = {\cdot}00155 + 1{\cdot}612 - 1 = 0{\cdot}613. \quad r/R = 0{\cdot}1 \text{ as before.}$$

Applying these values to Chart 5, gives db at f_i as 2·9. Reference to the auxiliary scales gives $f_\phi / f_i = 1{\cdot}33$. The following values are tabulated from Chart 6:

f/fi	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0
db loss ..	0.12	0.26	0.46	0.72	1.05	1.4	1.9	2.9
f/fi	1.5	2	2.5	3	3.5	4	4.5	5
db loss ..	6	9.3	12.5	15.1	17.5	19.6	21.5	23.2

Example 7.

The coupling of Example 4 is reduced to $k = 0{\cdot}0025$, retaining $Q_1 = 53$; $Q_2 = 212$; $f_c = 1\text{Mc/s}$.

Applying the principle by which (14) is obtained as a counterpart for (8), the corresponding formula for the transition case becomes,

$$\text{db at } f_i = 10 \log_{10}\left[1 + 3\left(\frac{m - k^2Q^2}{1 + k^2Q^2}\right)^2\right] \ldots (19)$$

and

$$f_i = f_c / 2Q\sqrt{m - k^2Q^2} \ \ldots\ldots\ldots\ldots\ldots (20)$$

evaluating, $\dfrac{m - k^2Q^2}{1 + k^2Q^2} = \dfrac{2{\cdot}125 - 0{\cdot}07}{1 + 0{\cdot}07} = 1{\cdot}92$. Applying this to Chart 5 as a value of $\omega_i^2 L_s C_p$ and using the left-hand edge (as if $r/R = 0$) the db at f_i is found to be 10·8. The frequency, given by (20), is

$$f_i = 10^6 / 212\sqrt{2{\cdot}005} = 6{\cdot}77\text{kc/s}.$$

Note that as kQ becomes small, the limiting value of transition frequency and attenuation becomes dependent upon m and Q only, so that for weak couplings the shape is dependent upon Q ratios and the frequency band upon mean Q.

CHARTS 7 & 8.

To produce the phase responses corresponding to the amplitude responses treated in Examples 1-3, 5 and 6, it is convenient to tabulate the reference points against f/f_ϕ from Chart 7 first, for both low and high frequency cut-off networks. For high frequency cut-off networks relative frequencies less than unity, and for low frequency cut-off networks relative frequencies greater than unity, that is the frequencies nearer mid-band, or with less than 90° phase shift, give reference figures on the upper half of the chart, while the frequencies beyond this point appear in the lower half of the chart.

f/fφ	0.01	0.02	0.03	0.04	0.06	0.08	0.1	0.15
Ref.	100	50	34	25.5	16.7	12.4	9.9	6.5
f/fφ	0.2	0.3	0.4	0.6	0.7	0.8	0.9	1.0
Ref.	4.8	3.05	2.1	1.05	0.7	0.45	0.2	0

The above reference figures appear on the upper half for H.F. cut-off networks and on the lower half for L.F. cut-off networks. The following are on the lower half for H.F. cut-off networks and the upper half for L.F. cut-off networks.

f/fφ	1.2	1.4	1.6	1.8	2	3	4	6
Ref.	0.37	0.7	0.95	1.23	1.5	2.7	3.8	5.9
f/fφ	8	10	20	30	40	60	80	100
Ref.	7.9	10	19.5	30	40	60	80	100

Applying these reference figures to Chart 8, and tabulating results for 6db peak and 5db at f_i, L.F. cut-off networks, and for 7·6db, ·1db peak and 2·9db at f_i for H.F. cut-off networks, the following table has been compiled:

f/fφ	0.01	0.02	0.03	0.04	0.06	0.08	0.1	0.15	0.2	0.3
6db peak L.F.	179° 42′	179° 24′	179° 8′	178° 49′	178° 12′	177° 36′	177°	175° 24′	173° 50′	170° 4′
5db at fi L.F.	178° 53′	177° 45′	176° 45′	175° 32′	173° 20′	171° 5′	168° 50′	163° 30′	158°	147° 30′
7.9 db peak H.F.	0° 14.2′	0° 28′	0° 41′	0° 56′	1° 25′	1° 55′	2° 24′	3° 36′	4° 50′	7° 45′
0.1db peak H.F.	0° 45′	1° 30′	2° 15′	3° 5′	4° 30′	6° 5′	9° 30′	11° 20′	15°	23° 30′
2.9db at fi H.F.	1°	2°	3°	4°	6°	8°	10°	15°	20°	30°

f/fφ ..	0.4	0.6	0.7	0.8	0.9	1.0	1.2	1.4	1.6	1.8	2.0
6db peak L.F.	166°	153°	143° 30′	131°	111°	90°	52°	36°	28°	23° 30′	19°
5db at fi L.F.	137° 30′	118° 30′	110° 30′	104° 30′	97°	90°	78°	69° 30′	63°	57° 30′	52°
7.9db peak, H.F.	11° 10′	21° 50′	30°	41°	62°	90°	133°	150° 30′	157° 30′	161° 20′	164° 40′
0.1db peak, H.F.	32° 30′	52°	61° 30′	70° 10′	80°	90°	106° 10′	119°	126°	132° 30′	139°
2.9db at fi H.F.	40°	59° 30′	68°	74°	83°	90°	103° 30′	112°	118° 40′	124°	130° 30′

f/fφ ..	3	4	6	8	10	20	30	40	60	80	100
6db peak L.F.	11°	7° 45′	5° 5′	4° 18′	3°	1° 32′	1°	0° 44′	0° 29′	0° 22′	0° 18′
5db at fi L.F.	35° 45′	26° 30′	17° 50′	13° 40′	10° 50′	5° 30′	3° 40′	2° 42′	1° 49′	1° 21′	1° 7′
7.9db peak, H.F.	171° 10′	173° 50′	175° 55′	177° 1′	177° 36′	178° 48′	179° 12′	179° 24′	179° 39.5′	179° 42.5′	179° 45.8′
0.1db peak, H.F.	153° 40′	160° 50′	167° 10′	170° 30′	172° 20′	176° 5′	177° 25′	178° 5′	178° 44′	179° 3′	179° 15′
2.9db at fi, H.F.	146° 20′	155°	163° 20′	167° 20′	169° 45′	174° 48′	176° 35′	177° 24′	178° 18′	178° 43′	179°

Notes from the Industry

1952 Institute of Radio Engineers Awards. The Board of Directors of the Institute of Radio Engineers, upon the recommendation of the Awards Committee, recently named the recipients of the annual I.R.E. awards for 1952. Dr. William Shockley, of the Bell Telephone Laboratories, was awarded the Morris Liebmann Memorial Prize in recognition of his contributions to the creation and development of the transistor. The Vladimir K. Zworykin Television Prize Award was conferred for the first time to D. B. Loughlin, of the Hazeltine Electronics Corporation, for his outstanding technical contributions to television. This award was recently established by V. K. Zworykin to encourage technical developments in fully electronic television.

Television — Simultaneous Transmission, Paris/London. Mr. Cecil McGivern, Controller of Television Programmes, and Mr. Imlay Watts recently went to Paris to study with the French television service the possibility of television relays between Paris and London.

As a result of this discussion the possibility of such relays is appreciably nearer. It would be a joint operation and can probably be achieved by using the Paris-Lille radio link which has just been established by Radiodiffusion et Television Francaise, and on which regular services will begin very shortly. From Lille to Calais and from Calais to London microwave gear will be used, and at some point on this part of the route a convertor will have to be employed to convert the French 819 line system to the B.B.C. 405 line system.

Radio Trades Examination Board. It has recently been announced that Mr. S. A. Hurren has retired from the chairmanship of the R.T.E.B., a position which he has held since its formation in 1941. Mr. E. J. Emery has been appointed as his successor, and Mr. H. A. Curtis has been appointed as deputy chairman, in view of Mr. Emery's many commitments.

The closing dates for the 1952 R.T.E.B. Servicing Examinations are: for the Radio Servicing Certificate, 1 February, and for the Television Servicing Certificate, 15 January. Regulations and examination entry forms may be obtained from the Secretary, R.T.E.B., 9 Bedford Square, W.C.1.

Navigational Aids in Ice and Tropics. Marconi's Wireless Telegraph Co. Ltd. have received an order for radio beacons to be erected in extreme climates—in the Antarctic at South Georgia, and in the tropics off Western Australia.

Two Marconi Type RB.109 radio beacons, which will be unattended, are to be established on desolate islands in the South Atlantic off the coast of South Georgia. They will provide half-hourly transmissions to enable vessels approaching the mainland to plot their positions by the inter-section of radio bearings at ranges of up to approximately 100 miles. The stations will be arranged to operate entirely automatically for three months in weather conditions with ambient temperatures ranging down to 20 degrees of frost, and wind velocities of up to 120 m.p.h.

The Type RB.109 radio beacon has an output rating of 20 watts and a frequency coverage of 200-415kc/s. It is suitable for marine or aeronautical services—combining the requirements of "Marker" and "Calibration" beacons in the single installation, with operation from A.C. mains or 50/100 volt batteries.

The station in the tropics is a radio navigational aid service for shipping making the dangerous "Penguin Shoals" off the Western Australian coast, and will be erected on Troughton Island. It will provide high power M.F. beacon transmission by automatic time control and on "Request," twin-channel H.F./D.F. facilities, and H.F./M.F. communication with vessels, the Lighthouse Department's telephone network and coastal stations.

The equipment includes: fully duplicated beacons type WB.8 feeding into a remotely situated 165ft vertical radiator; centre-site Adcock Direction Finding assembly type TFg.26/4; communication transmitter type TGS.541A with automatic 6-way frequency and aerial selection, and four H.F./M.F. receiving channels including the new 6-way crystal controlled receivers type RS.201.

The station features remote control facilities and the arrangements to utilize the D.F. "Sense" aerial to feed also the various receiving channels, so that the whole station can be controlled from the D.F. operating centre by a single watch-keeping operator.

BINDING OF VOLUMES

Arrangements have now been made for a binding service starting with the 1951 volume at an inclusive charge of £1.
Copies will be bound, complete with index and with advertising pages removed, in a good quality red cloth covered case blocked in gold on the spine.
Home and Overseas readers who wish to have their copies bound are asked to comply with the following instructions:—

(1) Tie the twelve issues (January to December, 1951) securely together before parcelling.
(2) Enclose a remittance for £1 and a gummed label bearing the sender's name and address.
(3) Enclose the copies, remittance and label in a closed parcel and address to:—

The Circulation Dept. (E.E. Binding), 28, Essex Street, Strand, London, W.C.2.
(No other correspondence is necessary)

★ ★ ★ ★

The following are also available from our Circulation Dept.:—
A limited number of Bound Volumes for 1951. Price two guineas, post free.
Binding Cases for the 1951 volume. Price 5s., postage 6d.
The Index for Volume XXIII (1951), free.
"Easibind" Cases for binding current issues, or complete volumes. Price 12s. 6d., postage 6d.

PUBLICATIONS RECEIVED

THE MECHANICAL PROPERTIES OF NICKEL ALLOY STEELS is a new publication dealing with the various types of steels, which are divided into two main groups, direct-hardening and case-hardening. Specification details (chemical composition, heat-treatment and mechanical properties) are given for each steel, together with representative test results which show the effect of mass. Tempering diagrams are included for the direct-hardening steels. General data includes tables showing the effect of tempering and sub-zero treatment on case-hardness, torsion test results, a graph showing the effect of surface condition on fatigue strength and a comparison of the various official tensile and impact test pieces in use. Copies of this reference book may be obtained, free of charge, from the Mond Nickel Co. Ltd., Sunderland House, Curzon Street, London, W.1.

MASTERY OF MEASUREMENT is a new Marconi catalogue designed to illustrate the wide scope of the company's activities in the fields of communication test gear, industrial measuring equipment and electro-medical apparatus. The catalogue is well presented on art paper, and includes clear diagrams and photographs of the instruments concerned. Marconi Instruments Ltd., St. Albans, Herts.

GLOSSARY OF PIEZO-ELECTRIC TERMS is Supplement No. 5 (1951) to British Standard 204:1943, which deals with the terms used in telecommunication. The terms used in Supplement No. 5 are therefore those used by engineers and others in the practical preparation of piezo-electric crystal units, and are engineering rather than crystallographic terms. It can be obtained from the British Standards Institution, 24 Victoria Street, London, S.W.1, price 1s., post free.

RADIO FOR MERCHANT SHIPS—PERFORMANCE SPECIFICATION FOR AN EMERGENCY RECEIVER is a new publication issued by the G.P.O. It gives a specification for the minimum performance of an emergency receiver, with loudspeaker-watching facility, for use in ships which have to be compulsorily fitted with radio. The booklet can be obtained from His Majesty's Stationery Office, Kingsway, London, W.C.2, price 6d., postage 1d.

"THE IRONMONGER" DIRECTORY OF BRANDED HARDWARE provides a ready source of reference for the many thousands of brand names which are in constant use in the hardware trade. It also contains a quite comprehensive list of tool manufacturers of value to electronic and radio engineers. Obtainable from the Circulation Manager, "The Ironmonger," 28 Essex Street, Strand, London, W.C.2, price 6s.

THE GUILDS' ENGINEER—SECOND ISSUE, 1951. This journal is jointly controlled by the Engineering and Radio Societies of the City and Guilds College. It contains several papers of interest to readers of ELECTRONIC ENGINEERING, such as "Broadcasting Engineering" by H. Bishop, "Frequency Modulation Receivers" by P. M. S. Hedgeland, and "Trend in the Design of Small Power Transformers for use in Communication Equipment" by E. S. Parkes. Copies of the journal may be obtained from "The Guilds' Engineer," The City and Guilds College, South Kensington, London, S.W.7, price 5s., inclusive of postage.

PHILIPS LIGHTING PUBLICATIONS—Philips Electrical Ltd. have recently published new editions of their leaflets on Sodium Lighting, Industrial Fittings for 40W 4ft lamps and Mercury Lighting, to bring them up to date. Their numbers are A.161, A.163 and A.166 respectively, and can be obtained free from Philips Electrical Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

RCA TECHNICAL PAPERS (1946 - 1950) INDEX, VOLUME II, lists substantially all published English-language technical papers on subjects in the radio, electronics and related fields, the authors of which were associated with the Radio Corporation of America (including its various divisions and subsidiary companies) at the time of the paper's preparation or at the time the work described in the paper was performed. It is obtainable from RCA Review, Radio Corporation of America, RCA Laboratories Division, Princeton, New Jersey, U.S.A.

Letters to the Editor

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

Standardized Abbreviations

DEAR SIR,—Your correspondent Mr. J. W. Godfrey has ranged over a variety of topics in his letter (October issue) on the subject of standardization, but he is chiefly concerned with the difficulties encountered in the use of abbreviations.

The problem of the manipulation of standard symbols and abbreviations is made unnecessarily difficult if a clear distinction is not made between these two uses of letters.

Abbreviations are shortened forms of the words intended to be used and, as far as abbreviations for units are concerned, are more often than not associated with specific numerical quantities:

e.g.,	ten amperes	10A
	five volts	5V
	fifty watts	50W
	four microfarads	4μF
	one millihenry	1mH
	seven megohms	7MΩ
		etc.

Letter symbols, on the other hand, are algebraic signs representing entities or parameters, possibly at a particular instant or period of a cycle, or with a maximum, minimum, total (etc.) value.

e.g.,	current	I,	I_{pk}
	voltage	V,	$V_{r.m.s.}$
	power	W,	$W_{inst.}$
	capacity	C,	$C_{max.}$
	inductance	L,	$L_{min.}$
	resistance	R,	R_{total}
			etc.

It is frequently necessary to employ additional devices, including italics, bold type, etc., for symbols, but never for abbreviations.

This point has apparently not been appreciated by Mr. Godfrey who, in a single paragraph, while speaking of abbreviations of the type H.T., R.F., etc., refers to "sinusoidal quantities where capital and lower case 'abbreviations' represent different values." Abbreviations by themselves do not represent "values" at all.

Thus, while one speaks of both "r.m.s. voltage" and "twenty volts r.m.s."
the symbol for the former is written—

$V_{r.m.s.}$

and the abbreviation for the latter—

20V r.m.s.

The distinction may be clearer if the example relates to current:

"peak current" is written I_{pk}
and "fifteen amperes peak" is 15A peak or 15A pk

not, I maintain, 15 A_{pk}, which means, if anything at all, fifteen times the peak "amperes" or current.

It may be thought that the commonly used "Ω" is a symbol not an abbreviation. but this is not so. The symbol for "resistance" is "R." The abbreviation for the unit of resistance, the ohm, is the Greek letter omega "Ω" but this is obviously employed to avoid confusion of the letter "O" with the cipher.

The battle between capital and lower case continues. However desirable the standardization of the one or the other for all abbreviations (with the exception, of course, of proper names) the supporters of neither side are showing signs of giving way, and what is the "obvious answer" to some is far from obvious to others, or it would have been adopted without question long ago.

The use of smaller type capitals has not been mentioned. These provide a third alternative. I am not sure if their use in Mr. Godfrey's letter was intentional or not, since they are commonly employed by ELECTRONIC ENGINEERING.

The majority of British journals (in the electrical field) seem to favour the use of lower case letter abbreviations. The British Standard BS.560:1934 "Engineering Symbols and Abbreviations" cannot apparently make up its mind on the subject. In the section "Explanatory Notes" and under the heading "Capitals" one reads:

"The use of capital letters . . . is in general discouraged. Capitals have, however been adopted . . . . (ii) where it is *the general practice to use capitals*."

That leaves us just where we started. (I understand that BS.560 is at present undergoing revision. Perhaps this problem will be faced squarely in the next edition.)

The paragraph in Amendment No. 1, Sept. 1945, to BS.560, which permits the use of lower case for abbreviations of adjectives, applies strictly to only five specific abbreviations found in the section "Machines and Transformers"; these are: A.C., D.C., L.V., H.V., and E.H.V., which are all given as capitals.

This principle has been extended to many similar abbreviations. The I.E.E. for example, "economizes further in respect of capital letters than does the B.S.I." (I.E.E. Handbook for Authors, Glossary p. 32.) The matter is then taken one step further, and in general nouns are spelled out in full in I.E.E. publications.

There remains the question of the abbreviations A.C. and D.C. I see no reason for objecting to "an a.c. motor" and "200V A.C." I question whether the form "an a.c. voltage of 200" has ever appeared in print previous to Mr. Godfrey's letter or is ever likely to do so again in the future, although admittedly it may be normal conversation to say "an a.c. voltage of 200" or, as is more likely, in spite of its tautology, "an a.c. voltage of 200 volts." In any case, this is not the only example where the appearance of a sentence may be improved by recasting it. The same may be said of the other point which apparently gives offence to many, that of beginning with the abbreviation thus: "A.c. voltages . . . ."

Alas for Mr. Godfrey's hopes of finality for many years to come with the British Standard on Letter Symbols for Electronic Valves BS.1409:1947; there is already a later (amended) issue, BS.1409:1950. But we are straying again into the field of symbols, and one or two points remain to be mentioned under the heading "abbreviations".

Most emphatically, there are indeed only three abbreviations for frequencies viz., c/s, kc/s and Mc/s, in spite of the arguments in favour of Kc/s, Mc/s or kc/s, mc/s, etc.

The subject of full stops is dismissed in a single paragraph. Only one point will be mentioned here; the wording of the paragraph from the Amendment No. 1 to BS.560:1934 which is referred to. It will be as well to quote this in full again.

"Full stops shall be omitted in all cases of single word abbreviations relating to units and quantities except where doubt may exist as to whether the letters given represent a complete word or abbreviation."

This rule gives the following as correct: in., ft, yd. What then of square inch, square foot, etc.? Does the phrase "single word abbreviations . . . " mean that full stops must be used thus: sq. in., sq. ft., sq. yd.?

What, too, of the phrase "where doubt may exist," which has been taken to mean that the abbreviations for "inch" (the only common abbreviation to which this can apply) must always be written "in." with a full stop?

To maintain consistency with the abbreviations "ft" and "yd" I would recommend using the full stop with "in" only in those very exceptional circumstances where confusion is really likely to result by reason of its omission. That such circumstances are exceptional will be obvious from a few examples:

ten in number	10 in number
two feet six inches	2ft 6in
four inches long	4in long
three inches in length	3in. in length

Generally then, the use of an adjective (long) rather than a noun (length) is sufficient to show clearly that "in" is the abbreviation for inch. Incidentally, "ten in.", meaning ten inches, is definitely incorrect. The unit should not be abbreviated if the quantity is written in words and not figures.

Yours faithfully,

H. A. WATERS.
Sidcup, Kent.

A Note on the Minimum Phase Principle

DEAR SIR,—The external properties of a 2-terminal linear electrical network, with time invariant elements, are invariably given as an impedance/frequency function or by its reciprocal, an admittance/frequency function. No other functions are in general use. The transfer properties of a 4-terminal network, on the other hand, are given in a wide variety of ways, e.g., as a voltage gain function, transfer impedance function, insertion transfer function, etc. In a recent paper in ELECTRONIC ENGINEERING[1] Tanner defines a minimum phase 4-terminal network using the voltage gain function. Linke[2] defines a minimum phase network using the insertion transfer function, while Bode[3] defines this class of network using the transfer impedance or admittance.

The object of this note is to show that if a network is a minimum phase network in terms of one transfer function, then it is also a minimum phase network in terms of the other transfer functions provided certain stability requirements are met. An explicit note of this result has not yet appeared in the literature, to the best of the writer's knowledge.

Transfer impedance

If we take the voltage at end *1*, (Fig. 1) E_1, to be acting in the first mesh and the current at end *2*, I_2, to be the mesh current flowing in the second mesh, then we have,

Transfer impedance
(from the first to the second mesh)
$\equiv Z_T = E_1/I_2 = \Delta/-\Delta_{12}$ (Bode p. 9)

Δ and Δ_{12} are functions of p, the complex frequency. For the network to be stable none of the zeros of Δ can lie in the right half p-plane (Bode p. 111). The transfer impedance Z_T of a stable network is a minimum phase function if Δ_{12} has no zeros in the right half p-plane

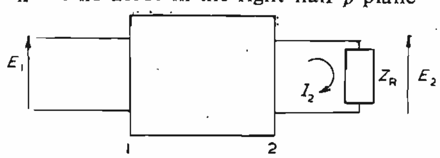

Fig. 1

(Bode p. 121). Since Z_R enters into the element in the second row and second column of Δ (Z_{22} say) only, Δ_{12} will be *independent* of the value of Z_R. The value of Δ will, of course, depend on the value of Z_R and we can write,

$$\Delta = \Delta^\circ + Z_R \Delta_{22}$$

where Δ° is the value of Δ when $Z_R = 0$. Thus if the transfer impedance of a 4-terminal network is of minimum phase type when the network is working into a certain impedance it will, in fact, be of minimum phase type when working into any impedance provided the network remains stable with the new termination (this will certainly be the case if the network and its termination are passive).

Voltage gain

In general, any minimum phase transfer function has no poles or zeros in the right half p-plane. For a network with a finite number of meshes the general transfer function is a ratio of two polynomials in p; the zeros of the numerator and denominator giving the zeros and poles respectively of the transfer function.

Voltage gain
(when network is terminated by Z_R)

$$= E_2/E_1 = \frac{I_2 Z_R}{E_1} = \frac{-\Delta_{12} Z_R}{\Delta}$$

Thus provided Z_R has no poles or zeros in the right half p-plane (i.e., Z_R is stable on its own[4]) and provided the whole network and termination is stable, then a minimum phase transfer impedance implies a minimum phase voltage gain function.

Current gain
(when network is terminated by Z_R)

$$= I_2/I_1 = \frac{I_2/E_1}{I_1/E_1} = \frac{-\Delta_{12}/\Delta}{\Delta_{11}/\Delta}$$

So provided the whole system is stable and remains stable when the input terminals (i.e., end 1 terminals) are open circuited,[4] then a minimum phase transfer impedance implies a minimum phase current gain function.

The well-known iterative and image propagation functions of classical filter theory (passive 4-terminal networks) will also be minimum phase functions if the transfer impedance is a minimum phase function since the propagation functions can be expressed as the logarithm of a voltage ratio (or a volt ampere ratio) when working into a certain impedance.

Insertion transfer function

With 4-terminal network inserted (Fig. 2),

$$\text{Load current} = I_2' = \frac{-\Delta_{12}}{\Delta}$$

where Δ_{12} and Δ refer to the complete network, including terminations. Δ is a function of both Z_R and Z_S but, as before, Δ_{12} is independent of Z_R and Z_S

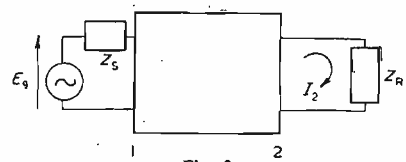

Fig. 2

since these only occur in Z_{11} and Z_{22} of Δ and are hence removed by omitting the first row and second column of Δ to obtain Δ_{12}.

Without 4-terminal network, i.e., with load Z_R directly connected to the alternator,

$$\text{Load current} = I_2' = \frac{E_g}{Z_S + Z_R}$$

$\therefore$ Insertion transfer function $\equiv$

$$I_2'/I_2 = \frac{-\Delta}{(Z_S + Z_R)\Delta_{12}}$$

So once again, provided the whole system is stable and an impedance equal to $(Z_S + Z_R)$ is open-circuit stable, a minimum phase transfer impedance function implies a minimum phase insertion transfer function.

The above has shown that if any particular transfer function of a passive 4-terminal network is of minimum phase type then all transfer functions are of minimum phase type. This also applies to active 4-terminal networks provided certain stability requirements are met.

Yours faithfully,

O. P. D. CUTTERIDGE, M.Sc.(Eng.).
Queen Mary College, London, E.1.

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2 LINKE, J. M.: A Graphical Approach to the Synthesis of General Insertion Attenuation Functions. *Proc. I.E.E.* 97, III, 179 (1950).
3 BODE, H. W.: Network Analysis and Feedback Amplifier Design. (Van Nostrand. 1945), p. 121.
4 BODE, H. W.: Network Analysis and Feedback Amplifier Design. (Van. Nostrand, 1945), p. 114.

Electronic Apparatus in the Laboratory

DEAR SIR,—The laboratory worker frequently finds that his experimental needs can be met neatly by addition of a simple unit such as a pre-amplifier, oscillator, or other contrivance to some standard item of the electronic equipment (such as cathode ray oscillographs, multi-stage amplifiers, counting-rate meters, etc.), which nowadays abounds. "Simple units" of the type referred to require power supplies for heater and anode of the valve or valves incorporated, and the necessity to provide these supplies either from batteries or from the mains makes the unit by no means so simple, small, convenient, and easy to "hook-up," as the circuit diagram drawn by the enthusiast suggests.

This letter is an appeal to manufacturers of commercial electronic equipment to state in their descriptive literature just what reserve capacity, if any, they consider to exist in the anode power pack and/or in any or all of the heater windings on the power transformer of their equipment. It could then be decided on reasonable grounds by the user whether these reserves were adequate to provide for the needs of his particular auxiliary unit. If some manufacturers refuse to guarantee that any extra load, however small, can safely be imposed on their systems, the writer would invite them nevertheless to fit extra terminals for access to these supplies, perhaps under a seal whose breakage would destroy all guarantee, and to give such information as their engineers can provide about the consequences of using them. However, a little reserve capacity of the nature indicated would be worth a few extra shillings, and its provision on apparatus of this type should be encouraged.

Yours faithfully,

JOHN SMITH,
Rugby.

Electrical Computing

DEAR SIR,—I hesitate to take part in a discussion with Mr. Bell and Dr. Porter, but I must state that a single ball and disk mechanism can be used for multiplying too varying quantities.

The rotational input to the disk is a velocity. This may if required be made proportional to a scalar quantity. The device is merely a continuously variable gear, and the other input which will normally be scalar is simply changing the gear ratio. The output velocity is the product of the instantaneous values of input velocity and gear ratio. The device does of course present some mechanical problems when used in this manner, but it has the advantage that occasional slipping at the friction surfaces will only cause error during the time when it is actually taking place.

Your readers may be interested also in the mathematical identity on which a price indicating petrol pump mechanism is based. This is

$$(x + y)^2 - (x - y)^2 = 4xy$$

It provides a method of replacing multiplication by the mechanically simpler processes of squaring, addition and subtraction.

Yours faithfully,

F. D. PRIESTMAN,
Coventry.

BOOK REVIEWS

Electrons and Holes in Semiconductors

By W. Shockley, Ph.D., 558 pps. McMillan and Co. Ltd., London, and D. Van de Nostrand Co. Inc., New York, 1950. Price £3 13s. 6d.

THE invention and development of the transistor by the research staff of the Bell Telephone Laboratories is considered by many to mark a new era in the history of electronics. Although it is unlikely that the transistor will ultimately displace the electronic valve, there is no doubt that for many electronic applications the transistor, when available in reliable form, will be preferred because of its robust and compact form and its modest demand on power supplies. The publication of a book on the subject of the transistor by one of the leading members of the Bell Telephone Laboratories research team, who has himself made notable contributions to the understanding of the operation of the transistor, is to be regarded as an event of note. The present book, however, aims at being far more than a description of the transistor and an explanation of its mode of operation. The author sets out to give an exposition of the basic theory of electronic conduction in solids, so far as it is necessary for an understanding of the transistor. This leads him into some very fundamental matters in quantum mechanics—a subject with which most electronic engineers have only a slight acquaintance. An attempt is made in the book, however, to teach engineers the necessary theory for understanding the processes of electronic conduction in solids.

The book is divided into three parts. In Part I (Chapters 1-4) a description of the transistor and a survey of its development is given. This part is easy to read and is written in a style which will appeal to engineers. In some ways it is the most satisfactory part of the book. In Part II a theoretical description of the basic phenomena underlying the operation of the transistor is given without going far into the actual mathematical arguments on which the theory is based. Such matters as conduction by "holes", mobility of electrons and "holes", Hall effect, etc., are dealt with and in Chapter 12 these ideas are specifically applied to the transistor. In some ways Part II is less satisfactory as a good deal of use has to be made of analogy, and one is left feeling that either the author might try to give a full explanation or take certain matters for granted. This section is meant primary for engineers, but many will not find it easy reading. Part III deals first with the quantum theory necessary for the full understanding of the fundamental processes of electronic conduction and in this case a mathematical treatment is freely used. Those unfamiliar with the subject will not find this part easy to understand as, of neeessity, much of the logical development of the quantum theory has had to be omitted. It seems to the reviewer that this theory would be better and more easily learned by reading some of the standard texts on the subject which lead the beginner more gently over the rough ground. To those already familiar with the theoretical background much of this part will be redundant. The last chapter, however, contains a good deal that is set out in a novel manner and makes very interesting reading.

One feels on reading the book that it might have been better if the author had written two books—one purely descriptive and one dealing with the theory on the assumption that the reader has a working knowledge of the quantum theory of solids. In this way the text could have been greatly reduced—as it stands the book is somewhat bulky and the cost rather high. Nevertheless, no one working on semi-conductor research or in fields allied to transistor development or application will want to be without a copy of the book, which indeed contains something of interest for all. Particularly valuable is the very full set of references given, and the earnest student will find great profit in carefully working out the instructive examples given at the end of each chapter.

R. A. SMITH

Advanced Practical Physics For Students

By B. L. Worsnop and H. T. Flint. 9th Edition. 745 pps. 493 figs. Methuen and Co. Ltd., August, 1951. Price 30s.

SINCE the original publication in 1923, many university students have been brought up on "Worsnop and Flint." The present volume is the ninth edition and has been revised and enlarged. The main revision seems to be the deletion of the original first chapter on "Calculus" and its replacement by a chapter on "Errors and Observations," while the enlargement seems to consist of the addition of four naive chapters on electronics.

While the scope of this work is too wide to allow detailed criticisms of all the subjects considered, in general it would seem that the experiments are classical, rather than modern, and designed to enable the student to pass university examinations rather than learn practical methods which he can use later in his scientific or technical life. It may be argued that a book of this nature is intended not as a laboratory handbook for practising physicists, but as a student's text, training the young scientists in fundamental methods rather than technology. Such a fundamental training is clearly imperative for any successful scientific work, but need it be done at the expense of technique?

For example in the chapter headed "Sound" there are five methods of finding the frequency of a note: by the syren, the tonometer, the falling plate, chronographically and by a stroboscope, the last three being applicable only to tuning forks. As a separate section there is a discussion of Lissajou's figure as an illustration of the equation
$1/p \arcsin x/a = 1/p \arcsin y/b - a/p$,
and in a fairly casual way mention is made of the fact that frequencies can be conveniently compared by means of Lissajou's figures. However, the fact that in any modern acoustical laboratory the determination of audio-frequency would almost certainly be achieved with a standard frequency source, and a cathode-ray oscilloscope is nowhere mentioned. What virtue does Cagniard de la Tour's Syren or Scheibler's tonometer possess over an R.C. oscillator and a cathode-ray oscilloscope?

The above example illustrates the grave defect of this volume—that although the experiments described are fundamentally sound and elegant, they bear little relation to the needs of the practising physicist or engineer. It is not impossible to assemble a series of practical experiments which, while being as fundamental and aesthetically appealing as those in this book, are at the same time in accordance with the needs of the reader when confronted with a real problem in a laboratory. Probably they would be of little assistance in passing a B.Sc. finals paper. For such a purpose the work under consideration would serve admirably, covering the whole field of the B.Sc. Special Physics course in a clear concise manner. The theoretical discussions of the principles underlying each experiment are most useful and the discussions of the principles underlying each experiment are most useful and the illustrations are clear and plentiful. It is well bound and well produced.

K. G. LOCKYER

Reports on Progress in Physics, Vol. XIV. 1951

Executive Editor: A. C. Strickland. 412 pp. The Physical Society. 1951. Price £2 10s.

ONCE again the Physical Society has issued a set of first class monographs on a wide range of physical topics. As we have come to expect in recent years, the subjects are extremely well chosen to cover particularly those subjects in which rapid advances are taking place.

In this volume there is a strong emphasis on light, five of the eleven articles being concerned with some aspect of spectroscopy and one, by E. Wolf, with the diffraction theory of aberrations. Two, on ultra-violet absorption spectroscopy by W. C. Price and on new techniques in interferometry by H. Kuhn, show how quickly new methods have developed. Two more deal with the detailed information on atomic structure which can be obtained: the anomalous fine structure of hydrogen and singly ionized helium by W. E. Lamb and nuclear effects in atomic spectra. Some of these will be mainly of interest to specialists in their own or allied fields, but the article by A. B. Meinel on the airglow and the aurora contains much of very general interest. Direct evidence has been obtained of hydrogen atoms in an aurora entering the atmosphere at up to 3,200km/sec (about 50keV) suggesting that fast protons from the sun may be the main exciting agents. Ultra-fast spectrographs of unprecedented proportions are mentioned as being on the way.

Two other articles are concerned with the atmosphere: that by N. C. Gerson on ionospheric temperatures, and by B. J. Mason and F. H. Ludlam on the microphysics of clouds. Here a microphysicist to watch the individual raindrops being formed seems needed; it is remarkable how much has been done without him. And though the authors make it clear that reliable artificial induction or prevention of rain is a long way off, basic knowledge required for such operations is well advanced.

Three articles are concerned with nuclear physics. It is a pity that M. Deutsch's article on angular correlations was completed just too soon to include Butler's theory of (d, p) reactions and the work which has arisen from this.

G. D. Rochester and W. V. G. Rosser give an excellent summary of new information on cosmic rays. This year, as last, it is clear that cosmic ray research, which proceeded very slowly for a decade or more, is one of the most fruitful sources of our knowledge of fundamental particles.

Finally, applications of nuclear physics in medicine are discussed by Professor Mayneord. Diagnostic and therapeutic measures, as well as possible hazards, are all discussed with an authority that makes the article of interest and value to very many outside the ranks of the physicists.

J. H. FREMLIN.

The Oxide-Coated Cathode

By G. Herrmann and S. Wagener: Vol. I, "Manufacture," 148 pages, 78 figures; Vol. II, "Physics," 311 pages, 154 figures. Chapman and Hall, 1951. Price: 21s. and 42s. net.

A COMPREHENSIVE review, in English, of the oxide-coated cathode has been wanted for some time. These two volumes adequately meet the need, and will no doubt quickly become established as a work of the first importance to all connected with the subject.

The authors are to be complimented on the thoroughness of treatment, not only of the technological aspects discussed in Volume I, but also of the physical principles argued in Volume II. Wherever possible, statements are supported by an adequate account of the relevant experimental evidence, and complete references to all works published up to the beginning of 1950 are given.

The section on the activation of the cathode, Vol. I, page 64 (not page 74 as indicated in the contents), includes important results of H. Huber's work on the activation of barium oxide by reduction. However, Fig. 34 does not show all that the text claims it does, and the statement that the maximum saturation current *increases* with temperature is obviously wrong and is contradicted on the next page. Chapter 5, Vol. I, deals with special cathodes for gas-filled tubes, rectifiers, etc.

Volume II begins with an account (from the standpoint of Fermi-Dirac statistics) of the thermal emission of electrons from metals, both uncontaminated and with absorbed materials, together with a chapter devoted to methods of measurement of work-functions. This is followed by an equally well-argued exposition of phenomena in ionic solids in preparation for the main chapters on the oxide-coating as an excess semi-conductor. There is an appendix on "flicker effect."

Errors are few, and for the most part obvious, e.g., the inverted index of Equation 14, Vol. II; BaO for $BaCO_3$, etc., p. 27, Vol. I. The English is not always concise and, although it may be "smooth" (as indicated in the preface to Vol. I), some readers may find it irksome.

For those who wish to appreciate the scientific principles underlying technical "know-how"; to obtain specific information about the properties of materials (there are no fewer than 47 tables giving these); to acquire a greater insight into the physics of solids, or to understand, as thoroughly as modern theory and practice permit, the mechanism of the oxide-coated cathode, these books will be found invaluable.

R. D. WATTS.

Introductory Nuclear Physics

By David Halliday. 558 pp. John Wiley & Sons Inc., New York. Chapman and Hall Ltd., London. 1950. Price 52s.

SINCE the war the number of serious students of nuclear physics has increased phenomenally. In so rapidly developing a subject it is always difficult to keep textbooks up to date. Professor Halliday has earned the gratitude of all teachers of nuclear physics by producing a really excellent book, including all the major developments of the subject up to 1949.

Great attention is paid to the physical principles involved. For example, many books leave the impression that loss of mass is a specific characteristic of nuclear reactions in which energy is liberated. It is made clear here that a similar though smaller loss of mass occurs in all chemical or physical exothermic changes.

Some familiarity with general atomic theory is assumed; for example, the angular-momentum quantization of electronic orbits. The book is, however, essentially designed for the experimentalist, as the conclusions of current nuclear theory are quoted for comparison with observation without giving detailed derivations.

At the end of each chapter is an exceedingly well-selected set of numerical questions which provide not only the best of all ways of seeing that the section is clearly understood, but leave the student with a helpful idea of the orders of magnitude involved.

The equipment and methods of the experimentalist are well described, the discussion of geiger counter action being outstandingly good.

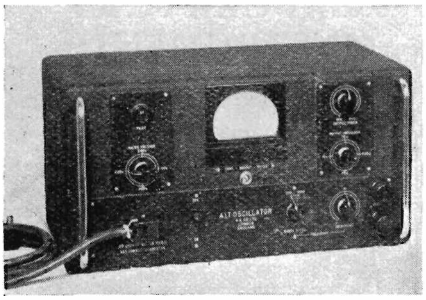
There are few misprints and most of these are obvious, such as e.V. for k.e.V. on p. 147 in giving the binding energies of K electrons. It is a pity that two of the few—Pa and Cu for Pu and Cm—occur in the very first figure.

Altogether it can be said that the book fills a long-felt want exceedingly well, and that its value greatly exceeds its not inconsiderable cost.

J. H. FREMLIN.

ELECTRONIC EQUIPMENT

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



Electronic Oscillator

(Illustrated above)

THE type 169 electronic oscillator is a recent addition to the Addison induction tracing equipment, and is designed to serve as a source of signal current for use in conjunction with search coil induction tracing equipment, and is particularly suitable for use as a generator for the location of cable faults, and the tracing of paths of cables and pipe lines.

It can be operated both from A.C. mains and battery, and has an output power of approximately 25 watts, with an output impedance adjustable between 0.3 and 80 ohms. It has facilities for operation at 200 and 1,000c/s with incremental frequency adjustment of approximately ±4 per cent. It has a power consumption of 110 watts and provision is made for matching to the load. Its power supply is 110V and 200-250V A.C. 40-60c/s, and 12V D.C. for battery operation.

A feature of the oscillator is an automatic keying circuit which interrupts the signal current periodically when in operation, so as to facilitate identification of the note produced in the headphones of the tracing equipment, and avoid confusion with extraneous noise and interference which may be picked up from neighbouring circuits.

Addison Electric Co. Ltd.,
163 Holland Park Avenue,
London, W.11.

New Amplivox Hearing Aids

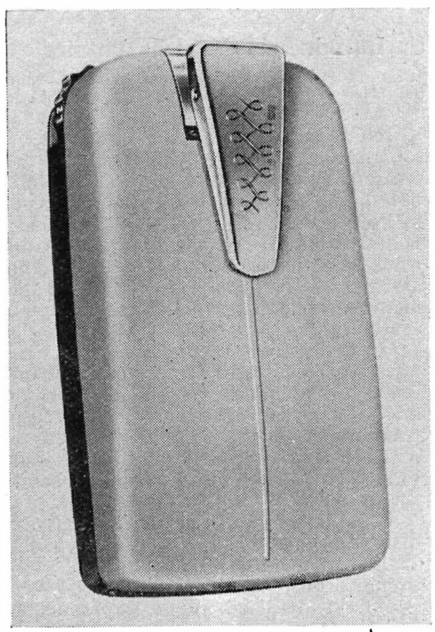
(Illustrated centre)

THE new Amplivox G series of hearing aids, smaller and lighter than their predecessors, have improved acoustic performance, permit closer prescription to individual requirements, and cost less in upkeep. There are two types, Model G for conductive deafness and Model GA for perceptive cases.

Model G has a maximum acoustic gain of 67db and power output of 136db. The percentage harmonic distortion is low at all levels below overload, and the frequency response smooth and free from peaks. Model GA has three degrees of automatic volume compression limiting output at will, and avoids distortion caused by peak-clipping or allowing the output stage to overload. The circuit has been adjusted so that the operating and recovery times do not affect the intelligibility of speech. Loud transient sounds are limited before their effect is perceived and the gain returns to normal rapidly, so that the sounds immediately following receive full amplification.

Alternative miniature magnetic earphones are available, E4W—wide range—with a frequency response extending up to 3,500c/s, and E4L—low tone—which has a cut-off frequency of 2,700c/s, but greater sensitivity throughout its range.

The instrument case is moulded in diakon, with spring-hinged lid to the battery compartment. The three-stage amplifier has plug-in valves, and the



microphone is fully floated to reduce clothing noise, the only contact with the case being through a thin rubber flange.

The battery upkeep for both models at present retail prices is approximately ½d. per hour.

Amplivox Ltd.,
2 Bentinck Street,
London, W.1.

The "Seraph" Loudspeaker

(Shown right)

THE "Seraph" loudspeaker has been manufactured in an attempt to produce a speaker that is free from cone-vibration resonances and from cross-modulation.

It consists of two 18in. diameter loudspeakers, with completely free edged cones, bolted face to face, and with the outside edges of the cones cemented together. Thus the two "Spiders" form the only suspension from the cone assembly.

It has a frequency coverage of 30-14,000c/s, and a voice coil impedance of 3·75, 7·5, 15 or 30 ohms. Its power capacity is 20 watts, and its flux density 13,500. The speaker weighs 29lb.

Seraph Sound Reproducers, Ltd.,
Abbeytown,
Carlisle.

RCA-12SP7 12in. Cathode-Ray Tube

THE 12SP7 is a 12in., directly viewed cathode-ray tube of the magnetic focus and magnetic deflexion type intended primarily for use in radar indicator service, but it is also useful in general oscillographic applications where a temporary record of electrical phenomena is desired. It utilizes the long-persistence, cascade phosphor P7.

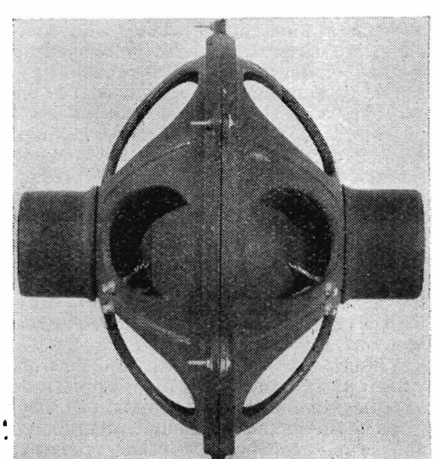
The faceplate of the 12SP7 is made of Filterglass to provide increased trace contrast and has so slight a curvature that it is almost a flat surface. The large, essentially flat surface facilitates the use of an external, transparent, calibrated scale.

The electron gun employed in the 12SP7 features a limiting aperture at the end of the electron gun to produce a sharper, rounder spot on the screen, especially when the tube is operated at high beam current, and hence provides greater effective resolution. Because of this feature, the 12SP7 is especially useful in those applications where pulse-modulated operation requires high grid-No. 1 drive and resultant high beam current.

RCA Photophone, Ltd.,
36 Woodstock Grove,
London, W.12.

"Telecene" Flux

"TELECENE" has been developed by Messrs. H. J. Enthoven and Sons, Ltd. to provide a liquid activated rosin-based flux which is rapid working and efficient. It is particularly applicable to those soldering operations in which it is preferable to use a solid solder wire rather than a rosin-cored solder.



It consists of rosin dissolved in methylated spirit, and contains an activating agent similar to that incorporated in the "Superspeed white Flash" solder, which gives the rosin a much more vigorous fluxing action.

Mass dip-soldering operations can be performed with this flux, such as soldering electric motor and dynamo armature commutator connexions. Other applications include: fluxing before pretinning the radial contacts of selector and uniselector multiple banks; dip-soldering coil winding ends and flexible cord multi-strand conductors, and anchoring the sensitive hair-springs of measuring instrument movements.

H. J. Enthoven and Sons, Ltd.,
89 Upper Thames Street,
London, E.C.4.

Venner Stop Watch Type MS

(Shown below)

VENNER Time Switches, Ltd. have recently produced an electrically operated stop watch. In operation the large hand revolves once in 10 seconds, and the small hand once in five minutes, while the main dial is calibrated in 1/10th seconds, and the inner dial is calibrated in 10's seconds.

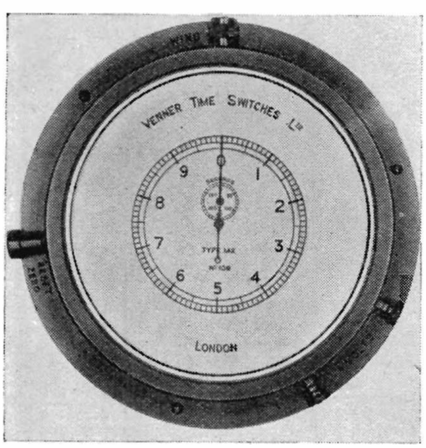
The escapement is of the lever type with jewelled pallets and smooth balance, and makes 30 beats per second. The hairspring is free from temperature error and is practically non-magnetic. The fly-back, or resetting mechanism, is actuated by heart-shape cams of specially hardened steel, this movement being extremely rapid when the resetting knob is depressed.

Starting and stopping is effected electrically by energizing and de-energizing the operating coils of an electromagnetic system embodied in the movement. Zero resetting and rewinding is effected manually.

The accuracy taken over a five minute run with the dial uppermost on full winding is 0·1 seconds fast and 0·05 seconds slow. The watches are supplied for operation at 4 volts or 12 volts.

The watch case is of robust construction and includes the resetting knob, winding stem and terminals for connecting to the external supply source.

Venner Time Switches, Ltd.,
Kingston By-Pass Road,
New Malden, Surrey.



Pye Miniature V.H.F. Walkie-Talkie

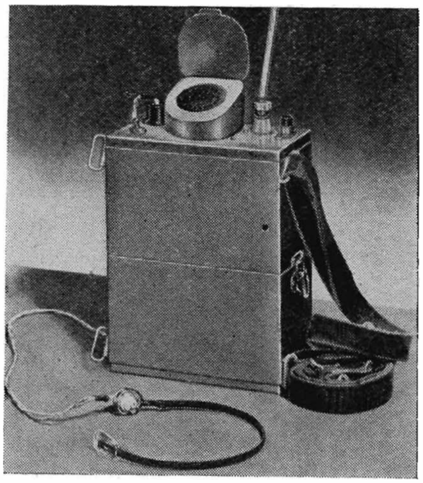
(Illustrated centre)

MESSRS. Pye, Ltd. recently introduced a miniature V.H.F. walkie-talkie equipment, which is 9½in. by 6½in. by 3½in., and weighs only 8½lb, including batteries.

The equipment is normally strapped to the chest of the operator, and has a built-in microphone and a single earpiece headphone, so that the hands are free except when actually transmitting.

The receiver operates on the superheterodyne principle. It has a crystal frequency tolerance of 0·003 per cent with 20pF shunt capacitance at 45°C. The signal/noise ratio is better than 10db at 10μV carrier 30 per cent modulated at 1,000c/s, with spurious responses at least 45db down. The audio response is 6dbs down at 300 and 2,500c/s.

The transmitter has a modulation capability of 95 per cent, and a modulator response of 6db down at 200 and 7,000c/s. The R.F. output is 0·1 watts. Both the transmitter and the receiver are



suitable for operation on spot frequencies in the range between 60-100Mc/s.

The controls are mounted on the equipment, with an on/off switch and a press-to-talk switch.

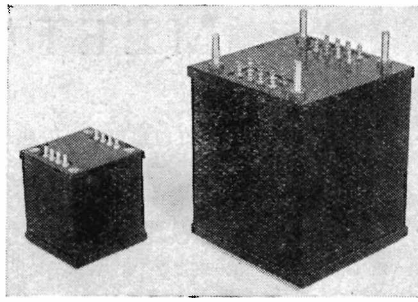
The power supply is from self-contained dry batteries, which have a life of 15hr L.T. and 75hr on intermittent operation.

Pye, Ltd.,
Radio Works,
Cambridge.

Totally Enclosed Transformers and Chokes

(Illustrated top right)

TO meet the demands of manufacturers for transformers and chokes designed to give greater climatic protection than that provided by those of open commercial construction, the Plessey Company, Ltd. has introduced a range of totally enclosed, semi-sealed units, particularly suitable for use in industrial and test instruments and in communications equipment. These transformers and chokes are vacuum impregnated with bitumen varnish, and enclosed in one of five basic sizes of bitumen filled cases. The electrical properties of the units may be varied



in manufacture over a wide range to meet manufacturers' operational requirements.

The fixing of the two smaller sized cases is such that they may be mounted normally or in an inverted position, while the remainder can be supplied with fixing bolts for mounting in either position, according to stated requirements.

The completed transformers are tested to specification limits for primary and secondary voltages, regulation, magnetizing current and full load power handling capacity, and are also subjected to flash and insulation checks.

Maximum operating temperature of these transformers is stated to be 110°C.

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

Proportional Controller

THE Kelvin and Hughes proportional controller is a similar instrument to the standard two-position controller with the addition of a proportional feature, and is designed for electric furnace applications where close temperature limits are of prime importance and a continuously changing heat input is required to maintain a constant controlled condition. Its advantages are: it is entirely electrically operated; lag due to low conductivity between measuring element and heat source is reduced; heat input against load requirements are continuously balanced, and proportional action is fully automatic.

In operation, a small addition to the standard controller enables limited zone proportional control to be obtained, approximately 2 per cent of the full scale reading. A variable capacitor is incorporated into the oscillatory circuit to produce a cyclical variation of the critical coupling position of the vane with respect to the two coils. Then as the vane enters the coils, external apparatus which has been continuously switched "on" up to this time, is now progressively switched between "on" and "off" until the valve is fully between the coils, when the apparatus remains in the "off" position. The vane leaving the coils causes the reverse operation.

The controller is supplied to operate direct from A.C. supplies of 110/125 and 220/250 volts at 50 cycles. The internal relay of the controller has a maximum capacitance of 5 amps at 250 volts A.C. (non-inductive load). The instrument is available for standard ranges from 0-400°C to 0-1,600°C, to operate with various thermocouple types.

Kelvin and Hughes, Ltd.,
New North Road,
Barkingside, Essex.

MEETINGS THIS MONTH

THE BRITISH INSTITUTION OF RADIO ENGINEERS

London Section

Date: January 9. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1.
Lecture: Crystal Triodes.
By: E. G. James, Ph.D. and G. M. Wells, B.A.

Scottish Section

Date: January 17. Time: 7 p.m.
Held at: The Natural Philosophy Department, The University, Drummond Street, Edinburgh.
Lecture: Television Aerials.
By: G. L. Stephens.

North Eastern Section

Date: January 9. Time: 7 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Lecture: Test Gear Design.
By: A. W. Wray, M.A.

South Midlands Section

Date: January 15. Time: 7.15 p.m.
Held at: The Exhibition Gallery, Public Library, Rugby.
Lecture: Propagation and Reception of Television Signals.
By: G. L. Stephens.

THE INSTITUTE OF NAVIGATION

Date: January 18. Time: 5 p.m.
Held at: The Royal Geographical Society, 1 Kensington Gore, S.W.7.
Lecture: Navigational Errors.
By: Wing Commander E. W. Anderson. O.B.E., D.F.C., A.F.C.

THE INSTITUTE OF PHYSICS

London and Home Counties Branch

Date: January 23. Time: 5.30 p.m.
Held at: The Institute of Physics, 47 Belgrave Square, S.W.1.
Lecture: Physics in Railway Research.
By: T. A. Eames, F.Inst.P.

Manchester and District Branch

Date: January 18. Time: 7 p.m.
Held at: The University, Manchester.
Lecture: Light, Colour and Radiation.
By: Dr. L. A. Sayce, F.Inst.P.

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.
Date: January 10.
Lecture: Electricity in Newspaper Printing.
By: A. T. Robertson.

Radio Section

Date: January 8.
Lecture: Two Electronic Resistance or Conductance Meters.
By: L. B. Turner, M.A., Sc.D.
Lecture: A Bridge for the Measurement of Dielectric Constants of Gases.
By: W. F. Lovering, M.Sc. and L. Wiltshire, M.Sc.
(Joint meeting with the Measurements Section.)
Date: January 16.
Lecture: Comparison of Ionospheric Radio Transmission Forecasts with Practical Results.
By: A. F. Wilkins, O.B.E., M.Sc. and C. M. Minnis, M.Sc.
Date: January 28.
Discussion: Should further Television Development be Concentrated on Colour to the Exclusion of Black and White?
Opened by: L. C. Jesty.

Education Discussion Circle

Date: January 23. Time: 6 p.m.
Discussion: Essential of a First Course in Electricity and Magnetism.
Opened by: H. Kayser, B.Sc.

Measurements Section

Date: January 22.
Discussion: High-Voltage Measurements and Tests.
Opened by: J. S. Forrest, M.A., D.Sc. and H. Tropper, Ph.D.
(Joint Meeting with the Supply Section.)

Cambridge Radio Group

Date: January 15. Time: 8.15 p.m.
Held at: The Cavendish Laboratory, Cambridge.
Lecture: The Sutton Coldfield Television Broadcasting Station.
By: P. A. T. Bevan, B.Sc. and H. Page, M.Sc.

Mersey and North Wales Centre

Date: January 7. Time: 6.30 p.m.
Held at: The Liverpool Royal Institution, Colquitt Street, Liverpool.
Lecture: Modern Developments in Electric Welding.
By: H. G. Taylor, D.Sc.(Eng.).
Date: January 14. Time: 6.30 p.m.
Held at: The Town Hall, Chester.
Lecture: Electricity in Newspaper Printing.
By: A. T. Robertson.
Date: January 21. Time: 6.30 p.m.
Held at: The Liverpool Royal Institution, Colquitt Street, Liverpool.
Lecture: Inhibited Transformer Oil.
By: W. R. Stoker, B.Sc.(Eng.).

North Eastern Radio and Measurements Group

Date: January 7. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Lecture: The Automatic Monitoring of Broadcast Programmes.
By: H. B. Rantzen, B.Sc.(Eng.), F. A. Peachey and C. Gunn-Russell, M.A.

North Midland Centre

Date: January 8. Time: 6.30 p.m.
Held at: Hotel Metropole, Leeds.
Lecture: Crystal Diodes.
By: R. W. Douglas. B.Sc. and E. G. James, Ph.D.
Lecture: Crystal Triodes.
By: T. R. Scott. D.F.C., B.Sc.
Date: January 29. Time: 6 p.m.
Held at: Lighting Scope Bureau, 24 Aire Street, Leeds.
Discussion: Is the Scope of Electrical Engineering Courses too Narrow?
Opened by: R. A. H. Sutcliffe. B.Sc.(Eng.).
(Education Discussion Circle Meeting.)

Sheffield Sub-Centre

Date: January 16. Time: 6.30 p.m.
Held at: The Grand Hotel, Sheffield.
Lecture: The Characteristics and Control of Rectifier-Motor Variable-Speed Drives.
By: P. Bingley.

North Western Centre

Date: January 8. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: Electricity in Newspaper Printing.
By: A. T. Robertson.

North Western Radio Group

Date: January 9. Time: 6.30 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: Analogies.
By: Professor M. G. Say, Ph.D., M Sc.

North-Western Utilization Group

Date: January 22. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: A New Power Stroboscope for High-Speed Flash Photography.
By: W. D. Chesterman, B.Sc., D. R. Glegg, G. T. Peck and A. J. Meadowcroft.

Scottish Centre

Date: January 22. Time: 7 p.m.
Held at: The Institution of Engineers and Shipbuilders. 39 Elmbank Crescent, Glasgow.
Lecture: Development and Design of High-Voltage Impulse Generators.
By: F. S. Edwards, M.Sc., F. R. Perry, M.Sc.Tech. and A. S. Husbands, B.Sc.(Eng.).

North-Eastern Scotland Sub-Centre

Date: January 9. Time: 7.30 p.m.
Held at: The Caledonian Hotel, Union Terrace, Aberdeen.
Lecture: The Operation and Maintenance of Television Outside-Broadcast Equipment.
Date: January 10. Time: 7 p.m.
Held at: The Royal Hotel, Union Street, Dundee.
Lecture: As at Aberdeen.

South Midland Centre

Date: January 29. Time: 7.15 p.m.
Held at: The Winter Gardens Restaurant, Malvern.
Lecture: A New Theory of the Magnetic Amplifier.
By: A. G. Milnes, M.Sc.(Eng.).

South Midland Radio Group

Date: January 28. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: Crystal Diodes.
By: R. W. Douglas, B.Sc. and E. G. James, Ph.D.
Lecture: Crystal Triodes.
By: T. R. Scott, D.F.C., B.Sc.

Rugby Sub-Centre

Date: January 16. Time: 6.30 p.m.
Held at: The Rugby College of Technology and Arts.
Lecture: The Use of Saturable Reactors as Discharge Devices for Pulse Generators.
By: W. S. Melville, B.Sc.(Eng.).

Southern Centre

Date: January 9. Time: 6.30 p.m.
Held at: The Polygon Hotel, Southampton.
Lecture: Domestic Electrical Installations: Some Safety Aspects.
By: H. W. Swann, O.B.E.
Date: January 16. Time: 6.30 p.m.
Held at: The Dorset Technical College, Weymouth.
Lecture: Servo Mechanisms.
By: Professor A. Tustin, M.Sc.
Date: January 23. Time: 7.30 p.m.
Held at: The R.A.E. College, Farnborough.
Informal Meeting.

Western Centre

Date: January 10. Time: 6.45 p.m.
Held at: The Sophia Gardens Pavilion. Cardiff.
Faraday Lecture: Sound Recording—Home, Professional, Industrial and Scientific Applications.
By: G. F. Dutton, Ph.D., B.Sc.(Eng.).

Western Utilization Group

Date: January 28. Time: 6 p.m.
Held at: The South Wales Institute of Engineers, Park Place, Cardiff.
Lecture: A Brief Review of Steel Works Electrical Equipment.
By: A. W. Ellis.

THE INSTITUTION OF ELECTRONICS

Southern Branch

Date: January 16. Time: 6.30 p.m.
Held at: Southampton University College, Southampton.
Lecture: The Synchrodyne.
By: D. G. Tucker, D.Sc., A.M.I.E.E.
Date: January 30. Time: 7 p.m.
Held at: H.M.S. Phoenix, Stamshaw, Portsmouth.
Lecture: Nuclear Fission and Release of Energy.
By: R. E. Ward, A.C.G.I., Wh.Sch.

THE RADIO SOCIETY OF GREAT BRITAIN

Date: January 25. Time: 6.30 p.m.
Held at: The I.E.E., Savoy Place, W.C.2.
Lecture: Overtone Mode Crystals.
By: A member of the staff of Standard Telephones and Cables Ltd.

THE SOCIETY OF INSTRUMENT TECHNOLOGY

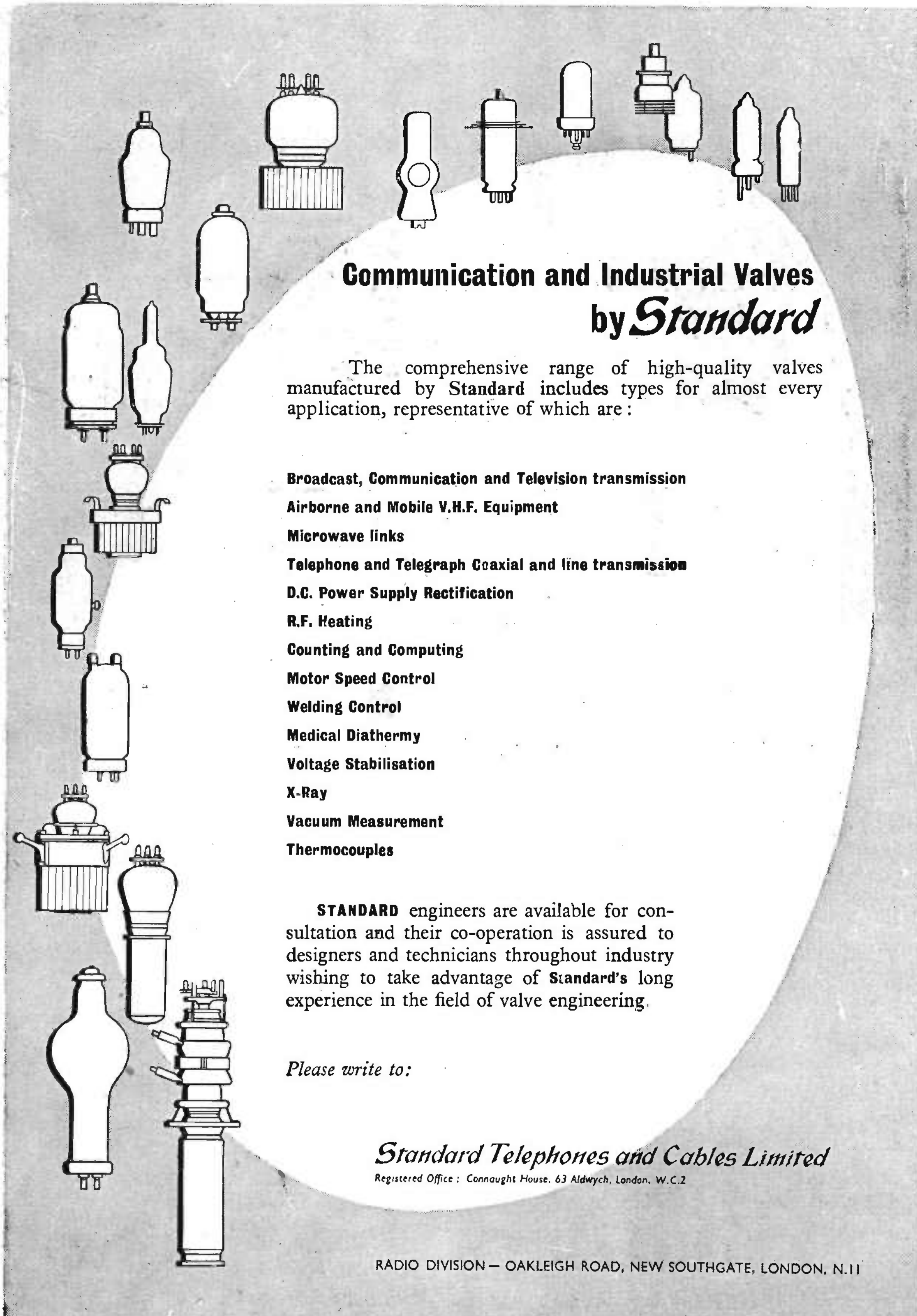
Date: January 29. Time: 7 p.m.
Held at: The Lecture Theatre, Royal Society of Tropical Medicine and Hygiene, Manson House, Portland Place. London. W.1.
Lecture: Some Mechanical Considerations in the Design of Electrical Servo Systems.
By: Professor A. Tustin, M.Sc.
(Joint Meeting with the Control Section.)

THE TELEVISION SOCIETY

Date: January 10. Time: 7 p.m.
Held at: The C.E.A., 164 Shaftesbury Avenue, W.C.2.
Lecture: Planning Television Programmes.
By: Alec Sutherland.
Date: January 25. Time: 7 p.m.
Held at: The C.E.A., 164 Shaftesbury Avenue, W.C.2.
Lecture: The Planning and Development of Television Broadcasting Stations.
By: P. A. T. Bevan, B.Sc., M.I.E.E.

Leicester Centre

Date: January 7. Time: 7 p.m.
Held at: Room 45. The Leicester College of Technology, The Newarkes, Leicester.
Lecture: Valves for Television Receivers.
By: K. S. Phillips.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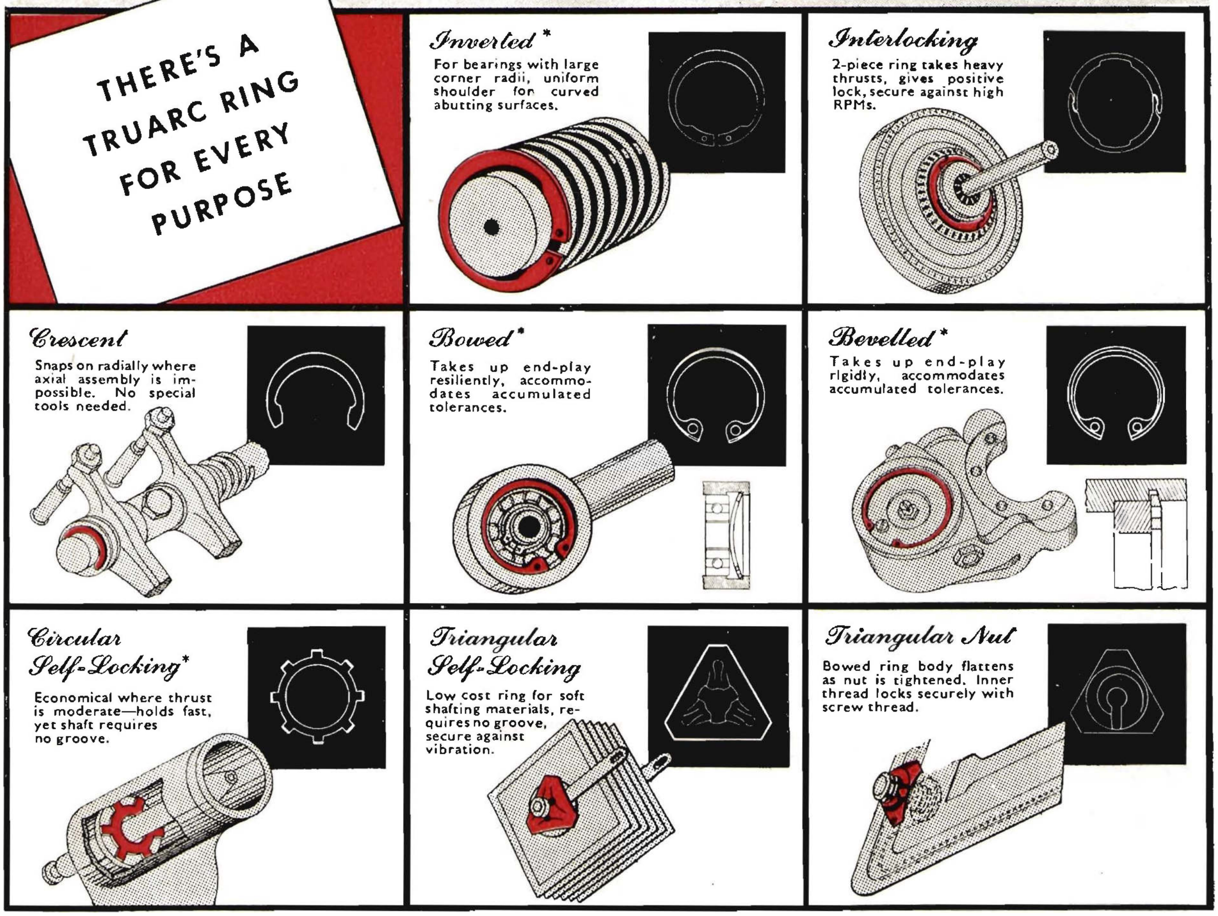

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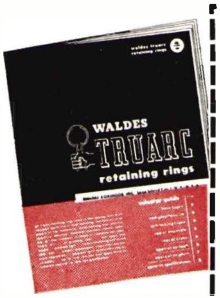

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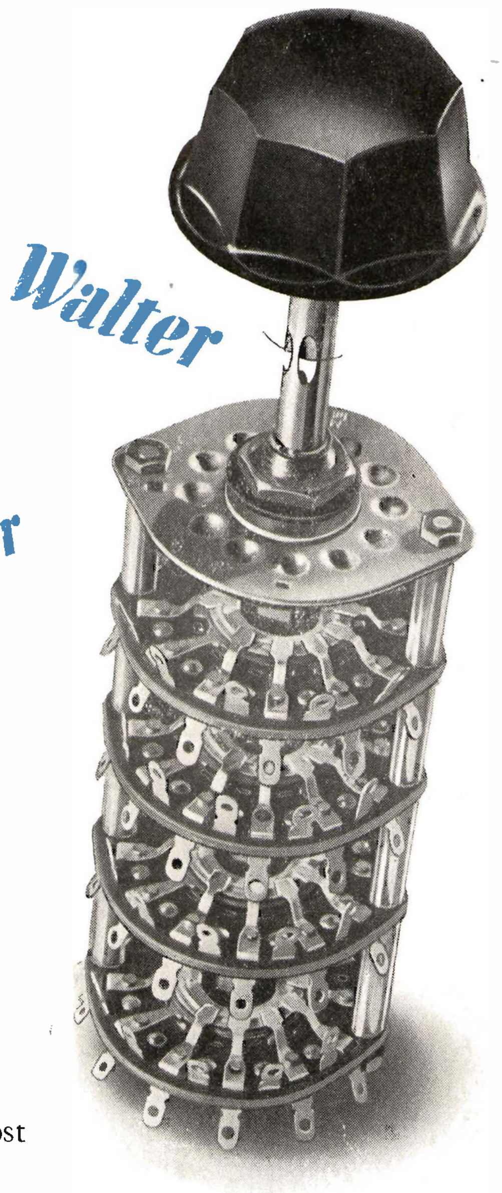

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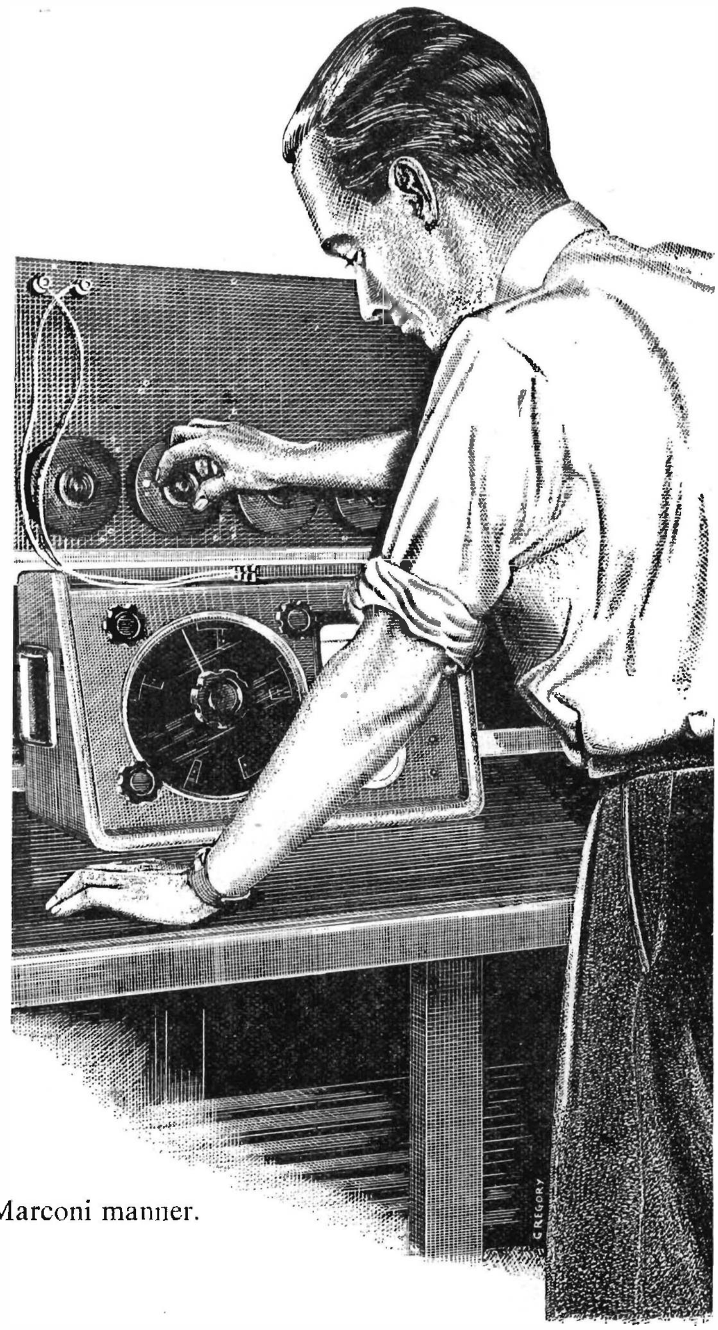

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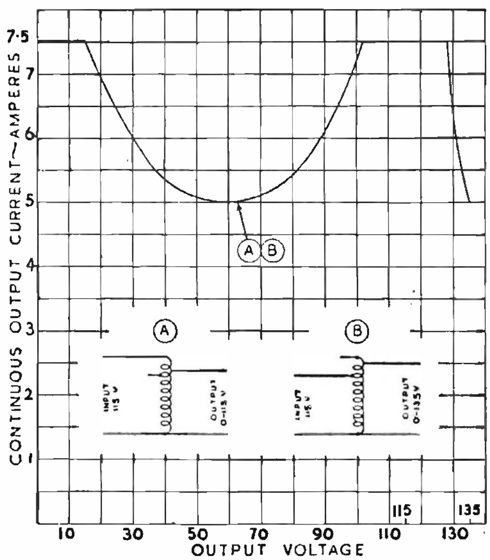

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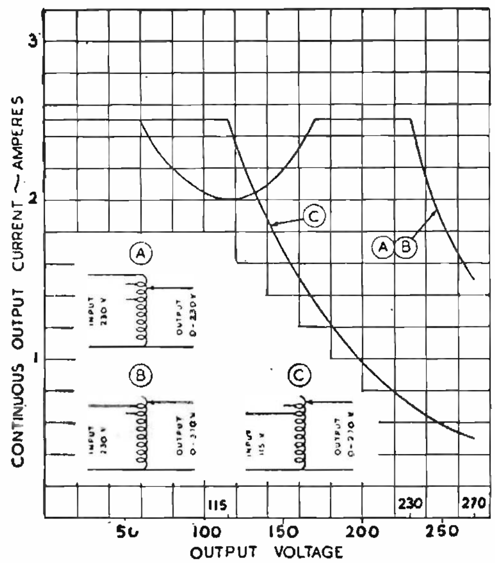

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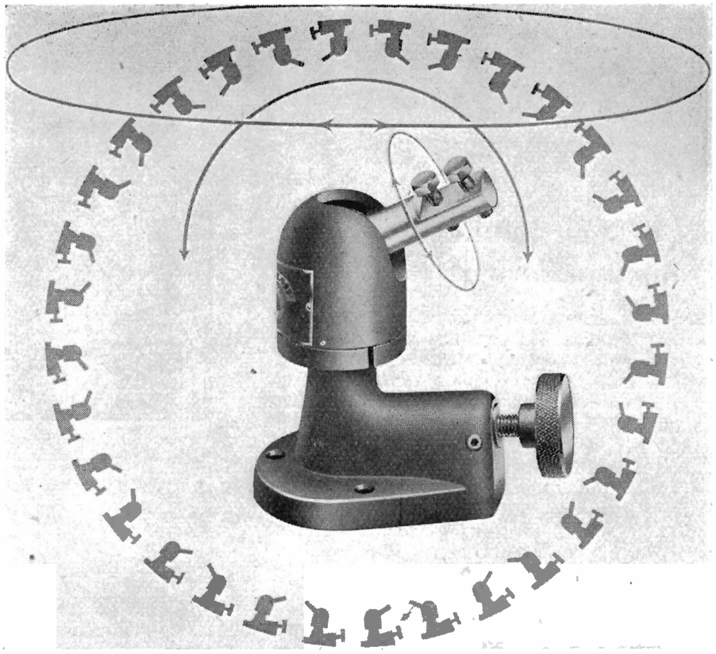

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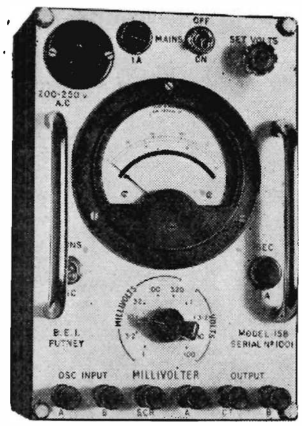
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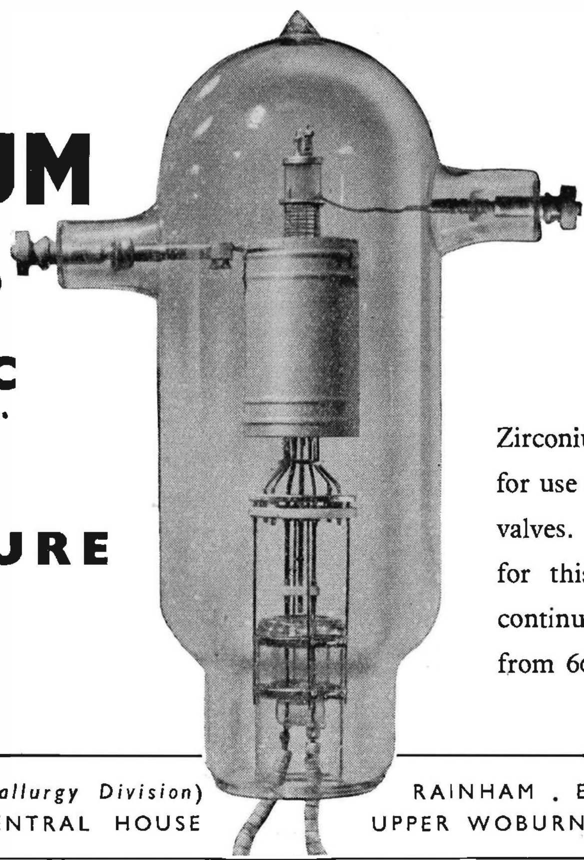

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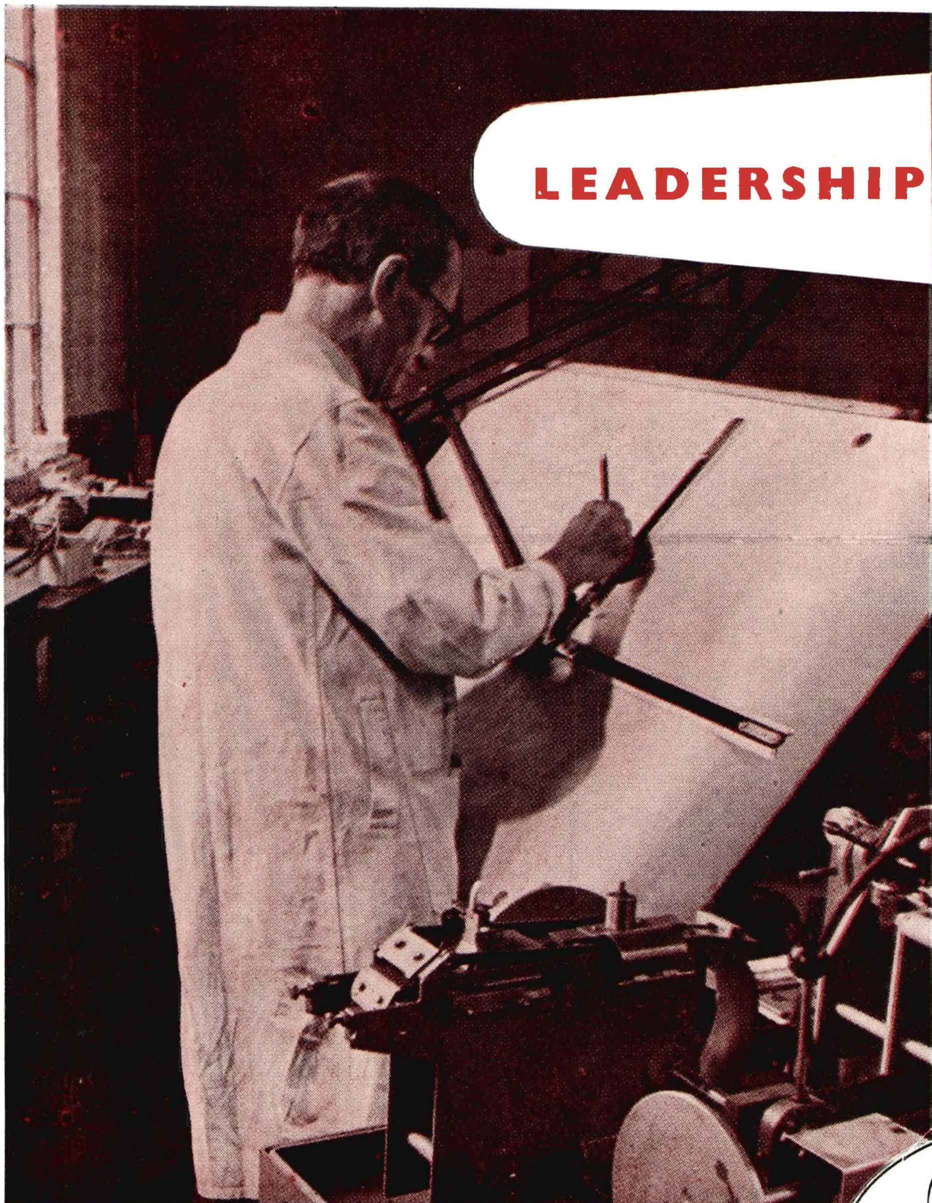

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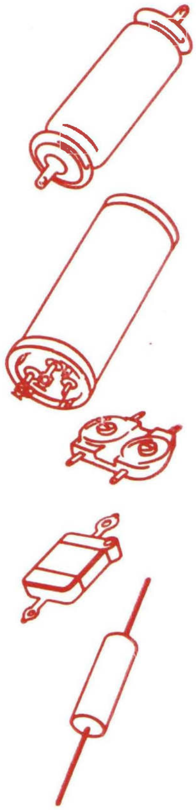

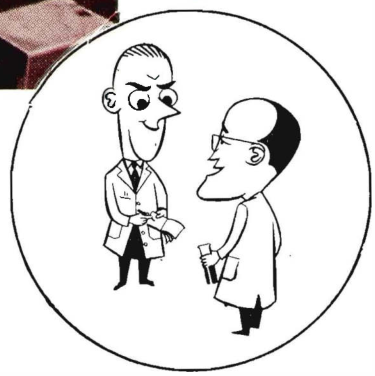

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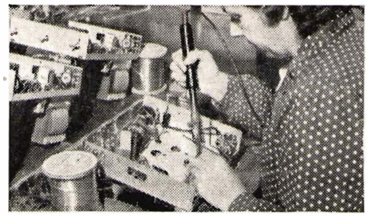

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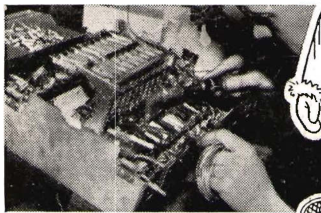

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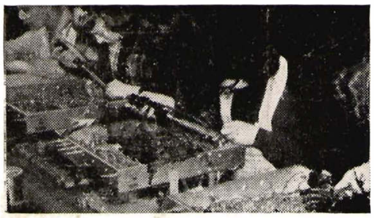

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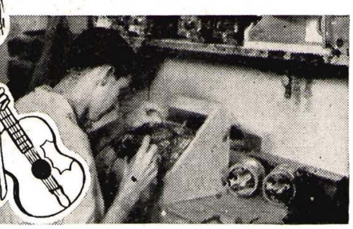

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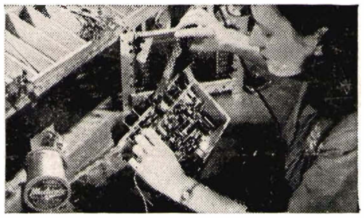

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