Electronic Engineering

JUNE 1952

Fine reproduction . . .

The Metrovick audio-amplifier is designed to give fine quality reproduction with the added advantages of being a self-contained unit, portable and attractive in appearance. It will prove ideal for Public Address work, educational authorities and similar organisations.

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

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R/E201

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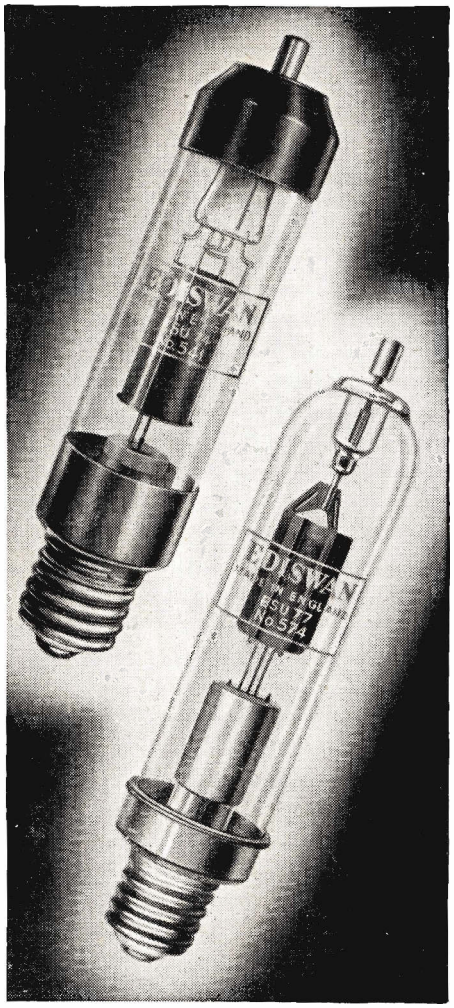
Half-wave high vacuum rectifiers

The Ediswan ESU 74 and ESU 77 are directly heated thoriated tungsten filament half-wave high vacuum rectifiers suitable for use in E.H.T. power supplies or as charging and damping diodes in pulse circuits.

RATINGS	ESU 74	ESU 77
Filament Voltage (volts) ...	4.0 V	4.0 V
Filament Current (amps) ...	11.5 A	12 A
Maximum Peak Inverse Voltage (volts)	40 kV	40 kV for pulse circuits 50 kV for normal rectifier applications
Maximum Peak Anode Current (amps.)	1.1 A	1.1 A
Maximum Mean Anode Current (mA)	—	—
Maximum Anode Dissipation (watts)	50 W	130 Watt
Maximum filament emission ... (amps.)	1.1 A	1.1 A
DIMENSIONS		
Maximum overall length (mm.)	250	270
Maximum Diameter (mm.) ...	60	61
Approximate net weight (ozs.)	7.0	—
Approximate packet weight (lbs.)	2.0	—
Approximate packed export weight (lbs.)	2.0	—
BASE	G.E.S.	G.E.S.
TOP CAP	Anode	Anode



EDISWAN

THE EDISON SWAN ELECTRIC COMPANY, LTD. 155 CHARING CROSS ROAD, LONDON, W.C.2
Member of the A.E.I. Group of Companies

EV85

CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements at the LINE RATE (if under 1" or 12 lines) is : Three lines or under 7/6, each additional line 2/6. (The line averages seven words.) Box number 2/- extra, except in the case of advertisements in "Situations Wanted," when it is added free of charge. At the INCH RATE (if over 1" or 12 lines) the charge is 30/- per inch, single column. Prospectuses and Company's Financial Reports £14. 0s. 0d. per column. A remittance must accompany the advertisement. Replies to box numbers should be addressed to : "Electronic Engineering," 28, Essex Street, Strand, London, W.C.2. Advertisements must be received before the 14th of the month for insertion in the following issue.

OFFICIAL APPOINTMENTS

ADMIRALTY: R.N. SCIENTIFIC SERVICE. The Civil Service Commissioners invite applications from electronic engineers or physicists for six permanent posts as Principal Scientific Officer or Senior Scientific Officer, according to age and experience. The posts are in the London area and Gloucestershire. For appointment as Principal Scientific Officer candidates must have been born on or before 31st December, 1920. They must possess a First or Second Class Honours Degree or be corporate members of the Institution of Civil or Mechanical or Electrical Engineers, or produce evidence of outstanding ability to carry out the duties required. Candidates must have research experience. For two posts a knowledge in one or more of the following fields would be advantageous; communication theory, mathematical statistics, audio-frequency equipment and telephone transmission (line or radio). Part of the work involves advanced study of the properties of conversational speech. For four posts knowledge is desired of high speed electronic switching and data storage and handling. Both digital and analogue techniques are relevant. Successful candidates will be required to take charge of teams which are responsible for the design of large scale equipment and its development to the prototype stage; one team will be engaged on research techniques relevant to the others. Inclusive London salary scale—Principal Scientific Officer (men) £1,075-£1,459, (women) £949-£1,280; Senior Scientific Officer (men) £812-£1,022, (women) £681-£917. Somewhat lower rates in the provinces. Exceptionally a starting salary above the minimum may be granted according to qualifications and experience. Superannuation provision under Federated Superannuation System for Universities. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S4141/52. Completed application forms must be returned by 12th June, 1952. Candidates born between 1st January, 1921 and 31st December, 1926 (inclusive), may be considered for appointment as Senior Scientific Officer but must apply through the Open Competition already announced (No. S53/52). W 2738

APPLICATIONS are invited by the Ministry of Supply for Physicists and Electrical Engineers for the following posts in the grade of Senior Scientific Officer or Scientific Officer at a Research Establishment, Near Sevenoaks, Kent. (1) Physicists with experience in Electronic circuitry problems for measurement of high speed transients. Ref. A 135/52A. (2) Physicist or Electrical Engineer with experience in radio communications. Experience in the application of electronic techniques to physical problems would be an advantage. Ref. A 136/52A. (3) Physicist interested in research into spark phenomena and transients. Ref. A 137/52A. (4) Physicist or Electrical Engineer with knowledge or interest in electronic circuitry for work on air-borne electronics. Ref. A 138/52A. Candidates should possess a first or second class Honours Degree in physics or electrical engineering, or equivalent qualification. For the senior grade the minimum age is 26 years and at least 3 years post-graduate research experience is required. Salary will be determined on age, qualifications and experience within the inclusive ranges: S.S.O. £781-£980, S.O. £417-£675. Rates for women somewhat lower. Posts are unestablished, but carry benefits under F.S.S.U. Application forms obtainable from the Ministry of Labour and National Service, Technical and Scientific Register (K) Almack House, 26 King Street, London, S.W.1, quoting appropriate Ref. No. Closing date 14th June, 1952. W 2741

APPLICATIONS are invited by the Ministry of Supply for posts in the Experimental Officer class at R.A.F. Signals Experimental Establishments to assist in one of the following: 1. (a) General experimental work in connexion with design of high power long distance radio telegraph systems or radio communications and radar systems D 171/52A. 1. (b) Aerial and feeder systems D 172/52A. 2. Site selection and installation design of large radio receiving and transmitting stations, radio telegraph terminal offices, or radio airfield approach and landing aids D 173/52A. 3. Experimental and development work associated with small electro-mechanical machines for machine telegraph systems D 174/52A. 4. Development and test of prototype mobile and portable radio and radar installations D 175/52A. 5. Engineering trials and investigations of modern automatic telegraph and line equipment D 175/52A. Post 1 (a) is located at Ruislip. Posts 1 (b), 2, 4 and 5 at Medmenham and Post 3 at Kidbrooke. Candidates should have a minimum Higher School Certificate with a Science subject as principal subject but those over twenty will generally be expected to have a Higher National Certificate or equivalent qualifications in applied physics, radio or electrical engineering. Experience in the duties outlined above is desirable and knowledge of R.A.F. Signals equipment would be an advantage. Salary will be assessed according to age, qualifications, experience and location within the following inclusive ranges: Experimental Officer (Minimum age 26) (Posts 1(a), 2, 3 and 4) £597-£786, Assistant Experimental Officer (Posts 1(a), 1(b), 2, 4 and 5) £264 (age 18)—£571. Rates for women somewhat lower. Posts are unestablished. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26, King Street, S.W.1, quoting Reference No. Closing date 14th June, 1952. W 2723

ASSISTANT (SCIENTIFIC) CLASS: The Civil Service Commissioners give notice that an Open Competition for pensionable appointment to the basic grade will be held during 1952. Interviews will be held throughout the year, but a closing date for the receipt of applications earlier than December, 1952, may eventually be announced either for the competition as a whole or in one or more subjects. Candidates must be at least 17½ and under 26 years of age on 1st January, 1952, with extension for regular service in H.M. Forces, but candidates over 26 with specialised experience may be admitted. All candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects: (i) Engineering and physical sciences. (ii) Chemistry, biochemistry and metallurgy. (iii) Biological Sciences. (iv) General (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing). Salary according to age up to 25: £236 at 18 to £363 (men) or £330 (women) at 25 to £500 (men) or £418 (women); somewhat less in the provinces. Opportunities for promotion. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S 59/52. Completed application forms should be returned as soon as possible. W 2744

COLLEGE OF TECHNOLOGY, Birmingham, Department of Physics and Mathematics. Research Assistants are required for a range of work on electronics, with particular reference to the performance and characteristics of thermionic valves and associated equipment. One appointment in mathematics may be made outside this field. Candidates must have a good honours degree in physics and/or mathematics, and preferably should be graduates of a University which awards higher Degrees for external study. There will be a small amount of teaching duty attached to the posts. The appointments will be for a maximum of three years. Salaries will be in accordance with the Burnham (Further Education) Scale, Assistant Grade A, i.e., (for men) commencing at £375 per annum with additional graduate and training allowances where applicable. In fixing the commencing salary, allowance will be made for teaching, and approved industrial, experience. Further particulars and form of application may be obtained from the Registrar, College of Technology, Suffolk Street, Birmingham, 1, on receipt of stamped addressed foolscap envelope. Completed forms should be returned to him not later than two weeks after the insertion of the advertisement. W 2710

GOVERNMENT DEPARTMENT requires Electronic Engineers for laboratory research and development work in telecommunications, autotelegraphy, carrier systems, V.H.F. pulse and filter techniques and circuitry. Candidates should preferably have some experience in one or more of these or related subjects and should be graduates in physics, telecommunications or electrical engineering, or hold Higher National Certificate or City and Guilds final, in radio subjects. Salary in accordance with qualifications and experience within the scales £623/728 and £445/623. Location: Cheltenham except that a period at Sevenoaks will be required for senior appointment. Application forms from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1, quoting D 184/52A. W 2755

MINISTRY OF SUPPLY require Physicists and Electrical Engineers with knowledge and experience of one of the following for posts in the Experimental Officer Class at a research establishment near Sevenoaks: (1) Electronic circuit design with particular reference to V.H.F. region or pulse technique. (2) Experimental and development trials of equipment, including field trials. (3) Development of electromechanical devices. (4) Measurement of transient phenomena in connexion with electrical and explosive equipments. (5) Radio for telemetry work. (6) Design of aircraft radar, some experimental flying will be required. (7) Development work on electrical components, preferably with experience of component design or inspection. Candidates should have a minimum of Higher School Certificate, with a science subject as a Principal subject, but those over 20 will generally be expected to have a Pass Degree or a technical qualification of similar standard, e.g., Higher National Certificate in Physics or Electrical Engineering. Salary will be assessed according to age, qualifications and experience within the inclusive ranges: Senior Experimental Officer (minimum age 35) £803-£1,033 p.a.; Experimental Officer (Minimum Age 26) £597-£754 p.a.; Assistant Experimental Officer (minimum age 18) £264-£555 p.a. Rates for women somewhat lower. The posts are unestablished. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1, quoting D170/52A. Closing date 14th June, 1952. W 2722

TECHNICAL AUTHOR required by Ministry of Supply at Chessington, Surrey. Qualifications: British, of British parentage; regular engineering apprenticeship or its equivalent, and sound practical experience of radio and radar equipment. Some experience as an instructor or technical writer, knowledge of printing and publishing, and possession of O.N.C. or equivalent qualification would be advantageous. Duties: Preparation of official instructional publications embracing airborne and ground centrimetric radar or radio communications equipment. Salary: Within range £607 (linked to age 30)-£718 p.a. Not established, opportunities for established pensionable posts may arise. Written applications, giving date of birth and education, full details of qualifications and experience of posts held (including dates) should be addressed to Appointments Officer, Ministry of Labour and National Service, 1-6 Tavistock Square, London, W.C.1, quoting reference J.U. 70 within 14 days of appearance of this advertisement. In no circumstances should original testimonials be forwarded. Only candidates selected for interview will be advised. W 2745

SITUATIONS VACANT

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

AERONAUTICAL SERVICE ENGINEER required. Duties will include installation, flight testing and servicing, for which a thorough practical and theoretical knowledge of A.C. and D.C. amplifier systems is required. A knowledge of Electro-mechanical servo systems and synchronous transmission systems would be an advantage. Preferential consideration will be given to applicants with previous electronic experience in possession of H.N. Certificate (or equivalent), or who have served a recognised engineering apprenticeship with subsequent experience in a technical capacity. Must be prepared to travel. Position will be permanent and pensionable after qualifying period. Commencing salary £450 p.a. Apply with full details of age, qualifications and experience to Sperry Gyroscope Co., Ltd., Great West Road., Brentford, Middlesex. W 2743

A FEW VACANCIES exist in the Research Laboratories of Marconi's Telegraph Co., Ltd., Chelmsford, for engineers for work on the circuit application of transistors. Although academic qualifications are valued and applicants should at least possess H.N.C., the type of work demands an experimental approach and a practical outlook is therefore essential. Applications stating age, qualifications and experience, quoting Reference 972/5 should be addressed to Central Personnel Services, English Electric Company, Limited, 24/30 Gillingham Street, London, S.W.1. W 2729

AN ENGINEER OR PHYSICIST is required for development work in methods of non-destructive testing and for the design, construction and maintenance of instruments for use in research. Preference will be given to candidates with good experience in electronics. The post carries superannuation. Application, stating salary required, should be sent to The Director of Research, Aluminium Laboratories, Limited, Banbury, Oxon. W 1472

A LARGE BRITISH firm in the light electrical engineering industry requires the following specialists for its electronic laboratory located in the North part of London:- An experienced Physicist having extensive knowledge of semi conducting materials and of the modern theory of material structure. Applicants should have a practical approach to problems and be able to investigate and check on the practicability of developments and ideas. Two electronic engineers thoroughly familiar with pulse circuit experimental techniques. The posts are permanent with contributory pension scheme and usual staff standards. Salaries will be considered individually and applicants should write to Box No. 528, Dorland Advertising, Ltd., 18/20 Regent Street, S.W.1, giving full details of qualifications, experience, age, and approximately salary range required. W 2585

A PROJECT ENGINEER is required by a firm of Instrument Makers to supervise the activities of a development laboratory engaged on projects covering specialised instrument and electronic equipment for aircraft. Applicants should possess a University Degree or Higher National Certificate in Electrical Engineering, or similar qualifications, and have had previous laboratory experience in this type of work, together with a knowledge of current design practice. Write, giving details of qualifications and experience to Box No. W 1477.

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

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

BRITISH TELECOMMUNICATIONS RESEARCH, LTD., a Company associated with Automatic Telephone & Electric Co. Ltd., and British Insulated Callender's Cables, Ltd., require an Engineer to undertake the preparation of technical literature on line and radio communications equipment and a certain amount of public relations work. The position will be permanent and is covered by the superannuation scheme. Five-day week. Application should be made to the Director of Research, British Telecommunications Research, Ltd., Taplow Court, Taplow, Bucks, giving full details of qualifications, experience and salary required. W 2724

BRITISH TELECOMMUNICATIONS RESEARCH, LTD., a Company associated with Automatic Telephone & Electric Co., Ltd., and British Insulated Callender's Cables, Ltd., require an Engineer with knowledge of patent procedure in their Patent Department for general duties on line and radio telecommunications equipment and systems. The position is permanent and covered by the superannuation scheme. 5-day week. Application should be made to the Director of Research, British Telecommunications Research, Ltd., Taplow Court, Taplow, Bucks, giving full details of qualifications, experience and salary required. W 2725

CHIEF OF LOUDSPEAKER TEST required by large and progressive engineering company situated in the London area. A sound practical and theoretical knowledge is essential. Permanent position. Staff Pension Fund in operation. Please write stating qualifications and experience, quoting reference No. 3816, to Box No. W 2707.

COTTAGE LABORATORIES LIMITED, require the following staff: (a) Project leader to control a division of electronic and electro-mechanical engineers. The applicant should be capable of leading a team of research and development engineers in a highly technical field. Starting salary will be according to ability, experience and age. (b) Senior electronic and electro-mechanical physicists or engineers. A physical and experimental outlook is desirable. The applicants must be capable of designing modern electronic circuits and of leading a group of assistant engineers. Starting salary according to age and experience. (c) Assistant Engineers interested in electronics and small mechanisms. There are prospects of rapid promotion in an expanding laboratory. Five-day week, excellent canteen and active sports club. Apply stating age, nationality, previous experience and salary required to the Manager, Cottage Laboratories, Ltd., Portsmouth Road, Cobham, Surrey. W 2703

DECCA RADAR, LTD., invites applications from designer draughtsmen for posts as section leaders on work of outstanding interest. The conditions are exceptional in scope for men with a flair for leadership and good design ability. Applicants should have Higher National Certificate or equivalent and wide experience of radar equipment design. Applications should be addressed to S.R.T., Decca Radar, Ltd., Research Laboratory, 2 Tolworth Rise, Surbiton, Surrey. W 2751

DEVELOPMENT ENGINEER with knowledge of metallurgy and electronics required for experimental work on ultrasonics in Research Department of scientific instrument makers in N.E. London area. Age 25/35. Write stating experience and salary required to Box No. W 2712.

DRAUGHTSMEN with experience of electronic work required by large light engineering company situated in the East London Area. Previous experience on electronic work essential. Positions are permanent and the usual staff privileges are available. Kindly state fullest particulars, quoting reference H71 to Box No. W 2728.

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

DRAUGHTSMEN are invited to make an appointment with E.M.I. Research Laboratories to discuss the several vacancies which are available in their Drawing Office at Hayes. Vacancies exist for both Mechanical and Electro Mechanical Designs Draughtsmen on a variety of equipment offering maximum interest and good prospects. Confidential interview arranged without obligation, and arrangements for Saturday morning interview if necessary. Consideration given to holiday arrangements. Long term employment prospects and excellent pension scheme. Apply giving fullest details of experience, qualifications, etc., in the first instance to Personnel Department (ILT/R), E.M.I. Limited, Blyth Road, Hayes, Middlesex. W 2601

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

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

ELECTRIC LAMP DEVELOPMENT ENGINEERS. Crompton Parkinson, Ltd., have several vacancies in their Lamp Development and Research Laboratories at Guiseley for experienced lamp or radio valve technicians capable of carrying out specific investigations and development schemes on filament lamps, discharge and fluorescent lamps, etc. The positions vacant offer good salaries and prospects of promotion to candidates of degree standard with some years of practical experience, who should write in confidence with full details to Ref. GLG, Crompton Parkinson, Ltd., Guiseley, Nr. Leeds. W 2733

ELECTRICAL test room assistants required urgently by well-known Scientific Instrument Company situated in North London. Technical education to O.N.C. standard an advantage. Box No. W 2560.

ELECTRICAL DRAUGHTSMEN required for design work by large light engineering company situated in the East London area and engaged in the production of light electrical equipment. Applicants should have experience in the design of light electrical and electro-mechanical components and the assembly and wiring of electrical equipment. Experience in aircraft electrical work an advantage but not essential. Positions are permanent and the usual staff privileges are available. Kindly state fullest particulars, quoting reference H65 to Box No. W 2727.

ELECTRICAL ENGINEER with first or second Honours Degree in electrical engineering required immediately by South London Company with international connexions. Some experience in high tension or power frequency is preferred. Age 21-30. Salary in accordance with age and experience. Full details to Box EE 612, L.P.E., 110 St. Martin's Lane, W.C.2. W 2746

ELECTRICAL ENGINEERING LABORATORY. Senior Technician. Queen Mary College (University of London), Mile End Road, E.1. Starting salary according to ability on scale £312 p.a. by £13 to £416 p.a. plus (a) London Weighting, (b) possible special qualification pay up to £39 p.a. Preference to an applicant with Ordinary National Certificate or experience of electronic apparatus and measuring instruments. Pension scheme. Letters only to the Registrar, stating age, experience, present work. W 1489

ELECTRONIC ENGINEER with good working knowledge of modern telephone practice and preferably sound recording, required for interesting new project with very big future. This is a top level job carrying a good salary and only engineers with the above qualifications and the ability to handle development and

CLASSIFIED ANNOUNCEMENTS
continued on page 4

Precision Resistance Wire
... PRECISION PACKED

JMC precision-drawn resistance wires are despatched in a pack that has been developed to set a new standard of protection. A transparent, robust plastic capsule guards against mechanical damage, dust, moisture and atmospheric fumes, and the wire is wound upon an accurately dimensioned light alloy reel of low inertia.

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A series of technical data sheets descriptive of our materials and products for electronic engineering and instrument manufacture is available on request.

JOHNSON, MATTHEY & CO., LIMITED, HATTON GARDEN, LONDON, E.C.1
Telephone : HOLborn 9277 *Birmingham : Vittoria Street, Birmingham, 1.*

GD204

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

manufacturing problems need apply. Send copies of references, details of career and a recent photograph in the first instance to Box No. W 1482.

ELECTRONIC ENGINEERS required for development work in the Gloucestershire area. Good academic qualifications and apprenticeship. Experience in one or more of the following desirable:- Control systems, D.C. Amplifiers, Computing Devices, Video Circuits, Microwave Techniques. Apply with full details of qualifications, age and salary required to Box No. A.C. 71443, Samson Clarks, 57/61 Mortimer Street, London, W.1. W 2604

ELECTRONIC ENGINEERS with Physics or Communication Degrees or with equivalent practical experience, required in the Camberley area for development of Cathode Ray Oscillograph equipment. Ability to handle complete projects including technical correspondence essential. Applicants should state age, qualifications, past experience and salary required. Box No. W 1471.

ELECTRONIC ENGINEERS with several year's research or development experience are invited to apply for posts with a well established company engaged on the development of precision laboratory instruments. App'icants should preferably possess an Honours Degree or equivalent qualifications in physics or light electrical engineering, although this is not essential as considerable practical experience is equally acceptable. The appointments are of a permanent nature for engineers of ability who are capable of developing new projects to the prototype stage, and offer scope for the exercise of individual initiative. The work is of absorbing interest and covers a wide range of electronic instruments. Salaries are commensurate with qualifications and experience. Applications should be made in writing to the Personnel Manager, Furzehill Laboratories, Ltd., Boreham Wood, Herts. W 1480

ELECTRONICS ENGINEER wanted, to take charge of production and assembly of electronic keyboard units. Good sound general knowledge essential, exceptional prospects for right man. Jennings Musical Instruments, Ltd., 119 Dartford Road, Dartford, Kent. W 1483.

ENGLISH ELECTRIC CO., LTD., Luton, have vacancies for Senior and Junior Electro-mechanical Engineers for work on a guided weapon project. A degree or Higher National Certificate in electrical engineering or physics essential. Experience in one or more of the following fields desirable: (i) Servomechanisms. (ii) Instrumentations. (iii) Electromechanical Design (iv) Vibrations (v) Electronics (vi) Electromechanical or electronic computing. Starting salary £450-£1,000. There are a few more senior posts open. Please write giving full details of experience and qualifications quoting reference 254 E to Central Personnel Services, English Electric Co., Ltd., 24-30 Gillingham Street, London, S.W.1. W 2735

ENGINEERS required for interesting development work on the design of all types of radio transformers. The work includes investigation of the use of new materials to transformer design. Applicants should write, giving full details to: Personnel Department (ED/76), E.M.I. Engineering Development, Ltd., Hayes, Middlesex. W 2759

ENGINEER REQUIRED to take charge of a section engaged on Research in connexion with Airborne receivers by Marconi's Wireless Telegraph Company, Limited, Chelmsford. An attractive salary will be offered to a suitable applicant who must have had good experience in this field. The position is one of responsibility and is permanent. Pension Scheme, etc. Please write in confidence giving full details and quoting reference 875A to Central Personnel Services, English Electric Co., Ltd., 24-30 Gillingham Street, London, S.W.1. W 2709

ENGINEERS AND PHYSICISTS with experience in the following fields are required by the G.E.C. at the Stanmore Laboratories: (a) servomechanisms (b) microwave aerials, transmitters or receivers (c) small mechanisms (d) electronic circuitry, (e) D.C. amplifiers (f) test gear for field trials. Preference will be given to men with good academic qualifications. Applications should be sent to the Staff Manager (Ref. GBLC/S/877) G.E.C. Research Laboratories, Wembley, Middlesex. W 2714

ENGINEERS required for development, servicing and instruction of electronic equipment. National Certificate Standard. Previous experience on electronics or radar desirable. Remuneration according to experience and qualifications. Apply—Labour Exchange, Rugby. (Ref.—Construction Department.) The British Thomson-Houston Co., Ltd., Rugby. W 2737

ESTIMATING ENGINEERS required by large progressive Engineering Company situated in the West Country. Applicants should have extensive knowledge of automatic work, multi and single spindles, Capstan work and small machined assemblies. The vacancy is of a permanent and progressive nature, pension scheme in operation. Applicants please write in confidence stating qualifications and salary required to Box No. W 2700.

EXPERIMENTAL DEPARTMENT of engine manufacturers in home counties requires engineer with Higher National Certificate or Degree, having basic knowledge of electronic circuits and practical familiarity with electrical instruments for measuring pressure, strain, vibration, etc. Experience desirable in use and construction of electronic equipment for engine development. App'y to Employment Exchange stating age, experience, salary required. W 2705

EXPERIENCED ENGINEER required by company in North West England for design and development of Television Aerials and associated components Write giving age, experience and salary required to Box Number W 1494.

FAULT FINDERS and Testers required for work on V.H.F. Communication Apparatus. Knowledge of Ministry Work desirable, but not essential. Apply to the Personnel Manager, E. K. Cole, Ltd., Southend-on-Sea, or to the local office of the Ministry of Labour and National Service. W 2730

FERGUSON RADIO Corporation Ltd., Great Cambridge Road, Enfield, Middx, have vacancies for Senior and Junior Development Engineers in the radio and television fields. Previous experience of circuit development work essential. Write giving full details of qualification and experience to Chief Engineer, c/o Employment Manager. W 2608

FERRANTI LIMITED have immediate vacancies for men with Electrical Engineering qualifications to undertake the advanced testing of naval anti-aircraft fire control equipment involving Electronics and servo mechanisms either in firms workshops or on board H.M. ships in home ports. Salary in accordance with age and experience between £356 and £650 per annum. Normal expenses plus a generous allowance are paid when working out. Previous experience of this type of work though desirable, is not essential. Forms of application from Mr. R. J. Hebbert, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference H.G.N. W 2537

FERRANTI LIMITED, Manchester, have staff vacancies in connexion with long-term development work on an important radio tele-control project at their new laboratories at Wythenshawe, South Manchester. (I) Senior Engineers or Scientists to take charge of research and development sections. Qualifications include a good degree in Physics or Electrical Engineering and extensive past experience in charge of development work. Salary according to qualifications and experience in the range of £1,000-£1,600 per annum. Please quote reference WS (II) Engineers and Scientists for research and development work in the following fields: Radar, radio and electronic circuits, micro waves, high power centimetric valves, vacuum and/or high voltage techniques, servo control and electro-mechanical devices. Qualifications include a good degree in Physics or Electrical Engineering or Mechanical Science, or equivalent qualifications. Previous experience is an advantage but is not essential. Salary according to qualifications and experience in the range £500-£1,000 per annum. Please quote reference WE. (III) Technical Assistants for experimental work in the fields listed in (II) above. Qualifications required: a Degree or Higher National Certificate in Electrical or Mechanical Engineering or equivalent qualifications. Salary in the range of £400-£600, according to age and experience. Please quote reference WT. (IV) Designers and Draughtsmen. Section leaders, leading draughtsmen, draughtsmen and junior draughtsmen, preferably with experience in any of the fields mentioned above. Salaries based on A.E.S.D. rates: in the range £330-£850 per annum with good allowances for special qualifications and experience. Please quote reference WD. The Company has a Staff Pension Scheme. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti, Ltd., Hollinwood, Lancs. Please quote appropriate reference. W 2721

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

INSTRUMENT assemblers and improvers required with some electrical knowledge for Scientific Instrument Company situated in North London. Box No. W 2561.

JUNIOR ENGINEERS required for interesting work on a V.H.F. Radio-Link System in the Field. Experience desirable but not essential. Headquarters near London. Salary according to qualifications and experience. Write giving full details and quoting reference ICD to Box No. W 2734.

KEEN YOUNG Electronics Engineer (19-23) required to assist on T/V aerial and associated component design and development. Write giving age, experience and salary required. N.W. area. Box No. W 1476.

LONDON ORGANISATION commanding a wide Home and Overseas trade in specialist electrical industrial driving applications up to 500 H.P., requires a qualified Electronics Engineer to study the firm's present mechanical /electrical control systems and collaborate in the experimental or permanent introduction of electronic devices where improvement on current methods appears to be possible from their employment. App'y with full particulars, training, experience, etc., to Box No. W 1473.

LOUDSPEAKER ASSISTANT ENGINEER required for design and development of loudspeakers for all radio and television applications. H.N.C. or equivalent qualifications. Some experience of acoustic properties an advantage. Please write in confidence giving full details of experience, quoting reference No. 3811, to Box No. W 2708.

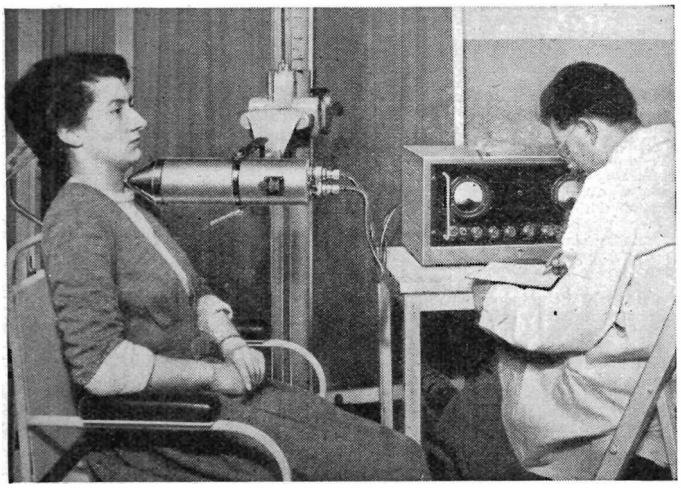
MULLARD EQUIPMENT, LIMITED, Wandsworth, have vacancies in their Engineering Dept., for the following: (a) Electrical Engineers (b) Electro-Mechanical Designers (c) Mechanical Designers. Applicants should preferably have had experience in the design of electronic equipment (transmitters, receivers, instruments, etc.). Permanent pensionable posts. Salary according to experience and qualifications. Apply Personnel Department, Mullard Equipment, Ltd, Brathway Road, S.W.18. W 2716

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

MURPHY RADIO, LTD., have vacancies in an expanding programme covering the field of domestic equipment and many branches of Electronic development for Engineering and

CLASSIFIED ANNOUNCEMENTS
continued on page 6

BETWEEN 1 AND 5 MICROCURIES OF RADIOIODINE SUFFICE FOR THYROID ACTIVITY MEASUREMENTS.....WITH THE NEW **EKCO** TYPE N509 SCINTILLATION COUNTER



Capable of operating directly all normal Scalers and Counting Ratemeters, it uses the E.M.I. type 5659 Photomultiplier Tube and a built-in wideband amplifier. It is already being used in the leading hospitals for Thyroid Activity Measurements, Brain Tumour Location and Blood Circulation studies. The standard collimator (shown in picture) is for use up to 1 MeV. Extras available include a larger collimator for up to 2.5 MeV and a non-directional protective cover.
SUPPLIES REQUIRED: 6.3v — 1A. 300v — 15mA. 1000/1500v — 10μA.

CHARACTERISTICS WITH RADIOIODINE UNDER TYPICAL WORKING CONDITIONS

COUNTING EFFICIENCY up to 60% using No. 1 Thallium Activated Sodium Iodide Crystal ½" dia. by ½" thick. BACKGROUND: 100/150 counts per minute. COLLIMATOR.—Geometry: 2.5×10^{-4} at apex. RESOLUTION: 8° rotation on crystal axis reduces count by 50%; 12° rotation on crystal axis reduces count by 80%. PROTECTIVE CAP.—Geometry: 0.45 with source touching cap.

SCALING UNITS · SCINTILLATION COUNTERS · COUNTING RATEMETERS
RADIATION MONITORS · VIBRATING REED ELECTROMETERS · G.M. TUBES
LEAD SHIELDING CASTLES · LINEAR AMPLIFIERS · COMPLETE COUNTING INSTALLATIONS · ACCESSORIES

EKCO
ELECTRONICS

Write for full details of Ekco instruments for radiosotope measurements to: E. K. COLE LTD., ELECTRONICS SALES, 5, VIGO STREET, LONDON, W.1

REDIFON...

★ WORLD WIDE RADIO COMMUNICATIONS
★ MARINE AND AIRPORT RADIO
★ H.F. INDUSTRIAL HEATING
★ LARGE SCALE AUDIO SYSTEMS

BROOMHILL RD., LONDON, S.W.18
CABLES: REDIFON, LONDON PHONE: VANDYKE 7281

'A COMPANY WITH A FUTURE'

SITUATIONS VACANT (Cont'd.)

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

Physics, or similar qualifications. These posts are permanent and pensionable and offer good opportunities for advancement. Applications giving full details of qualifications and experience should be forwarded to the Personnel Manager, Murphy Radio, Ltd., Welwyn Garden City. W 2757

MURPHY RADIO LIMITED have vacancies for Designer Draughtsmen in their Electronic Division. A varied programme ensures opportunity of widening experience with excellent prospects. Apply giving particulars of training and experience to : Personnel Manager, Murphy Radio Ltd., Welwyn Garden City. W 2607

MURPHY RADIO, LTD., wish to appoint a chief radio and television receiver designer to take charge of their electrical design laboratory. The successful applicant must possess good academic qualifications, preferably with some research experience and followed by several years in an industrial organisation engaged in television or allied fields. The post is pensionable and the salary paid will be commensurate with the high standard of qualifications required. Applications, which will be treated in strict confidence, should be addressed to the Director of Engineering, Murphy Radio, Ltd., Welwyn Garden City, Herts. W 2704

NEW ZEALAND. Applications are invited from suitably qualified persons for the undermentioned vacancies in the Civil Aviation Branch, Air Department, New Zealand. Radio Engineers—Professional Engineers competent in one or more of the following: design and/or installation of radio communications, navigational aids, radar and electronic equipment. Applicants must hold either an Engineering Degree specialising in telecommunications, electronics and/or Graduate membership of the Institute of Electrical Engineers or its equivalent. Salary will be up to £950 N.Z. per annum for Corporate Membership of Institution of Electrical Engineers or equivalent and up to £770 N.Z. per annum for non corporate members. Radio Technicians for base radio workshops, installation and general maintenance duties on radio/radar communications and navigational equipment. Applicants must hold a certificate of Radio Technology or equivalent, and experience in either pulse or continuous wave techniques is desired. Salary up to £770 N.Z. per annum as merited. Further details together with the necessary application forms can be obtained from—The High Commissioner for New Zealand, 415 Strand, London, W.C.2. mentioning this paper and quoting Reference No. 3/47/28. Completed applications should be lodged not later than 30 June 1952. W 2550

ONE OR TWO experienced Radar or Electronic Engineers, also Engineers experienced in Servo-mechanisms are wanted for a Guided Weapons project by English Electric Laboratory, Luton. Progressive posts with a starting salary of £600 to £1,000 per annum according to experience. Write giving full details quoting Ref. 456H, to Central Personnel Services. English Electric Company Limited, 24/30 Gillingham Street, London, S.W.1. W 2574

PHYSICIST OR ELECTRICAL ENGINEER required with advanced knowledge of electronics, particularly L.F. Amplification and the theory of servo mechanisms. Degree essential; age about 25; starting salary about £550. Write stating age, qualifications and experience to Sir Howard Grubb, Parsons and Co., Walkergate, Newcastle-on-Tyne, 6. W 1481

POST GRADUATE and Final Year University students in physics, electrical and mechanical engineering and metallurgy are invited to send details of their records to the Staff Manager (Ref. GBLC/S/878) Research Laboratories of the General Electric Co., Ltd., Wembley, Middlesex. A number of openings in interesting experimental research will be available during the coming months for men with outstanding ability and qualifications. W 2715

RADAR ENGINEERS, Senior and Junior required with B.Sc.(Eng.) or Chartered Electrical Engineer Diploma, or equivalent. Applicants should have had at least three years experience in works and laboratory with experience on Pu'se work preferably centimetric transmitters. Duties will involve acting as liaison between Development, Research Departments and the works. They will also be required to prepare Works Test specifications and advise on Test equipment. Write stating fullest particulars and salary required to Box No. W 2572.

SCIENTIFIC COMPUTER required to assist with design, development and research work in connexion with electrical networks. Minimum qualifications—inter Degree or Higher School Certificate including Mathematics. Experience in Computing, Mathematics, Physics or Engineering desirable. Initiative and interest in Mathematics and numerical work essential. Good salary and conditions of service. Apply Personnel Department, Telephone Manufacturing Co., Ltd., Sevenoaks Way, St. Mary Cray, Kent. W 2719

SEMICONDUCTORS—The Research Laboratories of The General Electric Co., Ltd., Wembley, Middlesex, have vacancies in the expanding field of semiconductors and semiconductor devices for physicists and engineers and also physicists with a chemical bias or physical metallurgists. Preference with be given to Honours Graduates with some previous experience. The openings offer good opportunities for advancement. Applications should be sent to the Staff Manager (Ref. GBLC/0/892) stating age, experience and qualifications. W 2711

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

SENIOR AND JUNIOR Electronic Engineers required for development of Guided Missiles and other work of national importance. Good academic qualifications, a thorough knowledge of low frequency electronic circuits including D.C. Amplifiers, and practical design experience of lightweight electronic equipment are desirable. The posts are pensionable and offer good scope for a man to learn and develop new techniques and advance his position. Apply to the Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middx., giving full details of age, qualifications and experience and salary required. W 2605

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

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

SENIOR ELECTRO-MECHANICAL ENGINEER required by new division of prominent engineering establishment in Northern Ireland to lead section engaged in development work on guided weapons. Degree or equivalent in electrical or mechanical engineering, with good practical experience in design of small precision electro-mechanical devices, servo systems or instruments. Good salary and prospects for man with originality, assistance given with housing. Send full particulars of age, qualifications and experience to Box No. W 1475.

SPECIALIST required with expert knowledge of development and production of carbon tracks for potentiometers. Apply Chief Engineer, Box No. W 1474.

S. SMITH & SONS (ENGLAND) LTD., Bishops Cleeve, Cheltenham, require the following staff: Senior Engineer—to lead a section in the design and development of small servo systems including the application of gyroscopic and magnetic amplifier technique. This is a permanent post and carries superannuation benefits and housing assistance will be given to successful applicant. Commencing salary £900 to £1,200 dependent on age, qualifications and experience. Ref. 4/EN/G. Senior Mechanical Engineer—to control design and development of a wide range of Aircraft Instruments and allied equipment. Applicants should have a sound technical education with previous design experience in pressure sensitive elements and intricate mechanisms. Salary £900 to £1,200 depending upon age and experience Ref. 5/EN/M. Development Engineers—for development of high grade test equipment in connexion with manufacture of automatic pilots and aircraft instruments. Work involves application of electronic techniques over a frequency range from zero to approximately 100 k.c. c.p.s. together with light electrical and mechanical engineering. Preference will be given to applicants with experience of applied measurements in one or more of the above engineering fields but the foremost qualification is a sound appreciation of fundamental engineering principles. Salary according to qualifications and experience. Ref. 1/EN. Development Engineers—senior and junior engineers experienced in the design of electronic test equipment including valve volt-meters, 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 dependent on qualifications and experience. Ref. 2/EN. Development Engineers—for work on auto control and servo systems. Applicants with experience in low frequency electronic techniques, including the use of magnetic amplifiers. Preference given to those with previous experience in designing equipment for aviation requirements. Salary according to qualifications and experience. Ref. 3/EN. Write quoting Reference Numbers and giving qualifications and experience to the Personnel Manager. W 2568

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

TECHNICAL ASSISTANTS required for interesting research and development work concerned with guided missiles. There are a number of vacancies for young men educated to about Inter B.Sc. or National Certificate standard and interested in light electrical and mechanical work. Previous experience in the electronics industry or in a technical arm of the Services would be useful but is not essential. Apply in writing giving full details of age, qualifications and experience to the Staff Manager (Ref. LPG/632) Stanmore Laboratories of The General Electric Co., Ltd., Stanmore Common, Stanmore, Middlesex. W 2740

TELEVISION ENGINEER required, experience in fault diagnosis, capable of using modern test equipment—circuit alignment by visual methods, etc. Situation 35-40 miles from London. Apply Box 87, Granthams Advertising, Reading. W 2702

TELEVISION ENGINEER required for Research Laboratory of Radio and Television Manufacturers. Must have recent experience in the design and development of television time bases and display circuitry. Write stating age, experience, qualifications, salary, etc., to the Personnel Manager, Bush Radio, Ltd., Power Road, Chiswick, W.4. W 2739

CLASSIFIED ANNOUNCEMENTS
continued on page 8

Tufnol Ltd.,

Perry Barr, Birmingham 22B,

announce that the word

TUFNOL

is their Registered Trade Mark

and the use by others of the word

TUFNOL *in connection with*

products not made from material

supplied by Tufnol Ltd., is an

infringement of the

Trade Mark Registration.

266

SITUATIONS VACANT (Cont d.)

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

TECHNICIAN required in the Department of Electro-physiology at Belmont Hospital, Sutton. Previous experience in electro-encephalographic practice desirable, but not essential Applicants should have a sound theoretical knowledge of amplifiers, experience or workshop practice and of servicing electrical instruments. Duties include maintenance of 2 Ediswan 6-channel electro-encephalographs and a wave analyser, designing and construction of experimental apparatus for research, and maintenance of a well equipped workshop. Some time is also spent in recording the E.E.G.s of patients. Salary £410 by £15 (3) by £20 (1)-£475 p.a. plus London weighting. Applications, giving age, full details of qualifications and experience, together with the names and addresses of two referees should reach the Group Secretary, St. Ebba's and Belmont Group Hospital Management Committee, Group Office, Belmont Hospital, Brighton Road, Sutton, within 10 days of the appearance of this advertisement. W 2754

THE BRISTOL Aeroplane Company Limited. invite applications for the following vacancies:- (a) Electronics Engineer, A.M. Brit. Radio Engineers, City and Guilds final tele-communications or equivalent, with a wide experience covering transmitters, receivers, aerials, test equipment, etc. (b) Electronics Instrument Maintenance Engineer, City and Guilds telecommunications or equivalent, with a wide experience of the maintenance of Electronic instruments. An ex-R.A.F. long service N.C.O. in the radio branch will also be considered. (c) Electronics Instrument Draughtsmen, City and Guilds tele-communications Grade 2, Ordinary National Certificate Electronics Engineering or equivalent, with experience in the design of Electronic Instruments and Apparatus. Application giving age, experience and qualifications should be addressed to the Ministry of Labour, 20 Nelson Street, Bristol, 1, and marked for the attention of the Personnel Manager, The Bristol Aeroplane Company Limited, Aircraft Division, Filton House, Bristol. W 2609

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

THE TELECOMMUNICATIONS DIVISION of the Plessey Company has immediate vacancies in its Engineering Department for the following personnel for work on long term defence and private venture projects. (1) Senior Engineers with experience in Electronic, Electro-Mechanical, or Line Telecommunications Development work. (2) Experienced Draughtsmen. (3) Experienced Drawing Office Checkers. (4) Experienced Tracers. Applicants should be of British birth. There are excellent prospects and very adequate salaries available for the right people. Apply, in confidence, to the Personnel Manager, The Plessey Company Limited, Ilford, Essex, quoting reference T.E.D. W 2742

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

TWO GRADUATES, one senior, one junior, required for work in Electronics Section of laboratory engaged in Physics Research. The function of the Electronics Section is primarily to design and build control and measuring gear for the laboratory, including Sections working on Electron Microscopy, Nuclear Physics, Semi-Conductors and Physical Metallurgy. Two other posts are vacant for work on new project requiring men with Ph.D. or Honours Degree and at least two years post graduate experience and having interest in work on radio frequency power circuits. Applications in writing stating age, qualifications and experience to Personnel Officer, Associated Electrical Industries, Limited, Research Laboratory, Aldermaston Court, Aldermaston, Berkshire. W 2718

UNIVERSITY GRADUATES in physics or electrical engineering are invited to make application regarding vacancies in an engineering department now being established about 30 miles from London for development work on airborne electronic equipment and instruments. The posts are permanent. Some previous experience in the theoretical and practical aspects of such development work is required. A knowledge of radio frequency measurements would be an advantage. Write giving details of qualifications and experience to Box No. W 1479.

WANTED A GRADUATE in physics, chemistry or electrical engineering or equivalent to be trained in the capacitor laboratory on the development of new materials, and the exploitation of new manufacturing techniques. No previous experience is necessary, and there are excellent prospects of advancement. Apply to Personnel Department, Standard Telephones & Cables, Ltd., North Woolwich, London, E.16, stating age, qualifications and salary required. W 2726

Further "Situations Vacant" advertisements appear on page 51 in displayed style.

SITUATIONS WANTED

DEVELOPMENT ENGINEER for application of high power ultrasonics to industrial or laboratory processes. 20 years' experience with specialisation in electronics. Initial Salary: £750 p.a. Box No. W 1493.

ELECTRONIC ENGINEER (28), A.M.I.E.E., A.M.Brit.I.R.E., seeks technical/executive appointment. Wide experience in telecommunications and electrical engineering. Apprentice trained. Present serving Captain REME, available after 1st October. Box No. W 1490.

ELECTRONICS TECHNICIAN Medical experience, complete apparatus built without supervision. Requires post where ability, enthusiasm and loyalty are valued above respect for bureaucracy. £550. Box No. W 1492.

ENGINEER, 32 H.N.C. and C. and G. Wide laboratory and factory experience of electrical and electronic instruments and measurements, telecommunications, radar, etc. Seeks post which offers suitable rewards for hard work and ability. London area preferred but all offers considered. Salary about £750 p.a. Box W 1486.

LABORATORY TECHNICIAN layout and complete construction electronic equipment from theoretical diagram without supervision skilled Engineer and Draughtsman. Box No. W 1448.

TECHNICAL PUBLICATIONS. Capable engineer-writer conversant all aspects to production of finished publication including art work, typography and layout, desires change. Prepared to assume charge or organise publications department. Write BM/CKAM, London. W.C.1. W 1478

SKILLED scientific glassblower, 16 years' bench experience, wants research dept. or lab. position: London (Central; North; West). Box No. W 1487.

SERVICE

INJECTION MOULDING capacity available for electronic components in polythene or P.V.C. up to 4 oz. Enquiries invited. R. Lowther, Ltd., St. Vincent Street, Manchester, 4. W 1485

YOUR COPIES BOUND, handsome volumes imit. Blue Leather, Gold Lettering. 10s. 6d. each, post free. C.W.O. Jerome Alcock, Cheadle, Stoke-on-Trent. W 1384

FOR SALE

AMERICAN GEC variable reluctance pickup with fully tone-compensated preamplifier. Sapphire stylus, brand new. £10. Douglas, 118 Raleigh Street, Nottingham. W 1496

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

40,000 ANTI-VIBRATION Chassis Mountings 4 and 8 lb. capacity. Spring type, must clear. £8 per 1,000. Jack Davis (Relays), Ltd., 36 Percy Street, London, W.1. W 1488

DOES YOUR BUYER KNOW we could produce your instrument making and light engineering requirements? We make complete instruments, assemblies and prototypes to your specification. Also sheet-metal, capstan and presswork. Highest standards at competitive prices. A.I.D. approval pending. Sherwood Products, 5 Rosemont Road, N.W.3. Ham. 6655. W 1497

EMITAPE. Secure your Recording Tape from "His Master's Voice" Showrooms, 363 Oxford Street, W.1. Mayfair 1240. W 2583

FOR DISPOSAL redundant laboratory equipment in good condition. For details contact Purchasing Dept.: Belling and Lee, Ltd., Cambridge Arterial Road, Enfield, Middlesex. W 2732

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

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

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

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

WEBB'S 1948 Radio Map of the World, new multi-colour printing with up-to-date call signs and fresh information; on heavy art paper, 4s. 6d., post 6d. On linen on rollers, 11s. 6d., post 9d. W 102

EDUCATIONAL

BATTERSEA POLYTECHNIC, London, S.W.11. Full-time Courses are available in preparation for the Degrees of the University of London in the faculties of Science and Engineering. B.Sc. Special in Chemistry, Physics and Mathematics. B.Sc. (Engineering) in Civil, Electrical, Mechanical and Chemical Engineering. B.Sc. (Engineering) Metallurgy, and for the Associateship Diploma of the Battersea College of Technology. Faculties for full-time research and Post Graduate Study in all faculties are available. New Session will commence on Monday, 22nd September, 1952. Enrolments should be made as soon as possible. Forms of application can be obtained from the Principal. W 2720

FREE! Brochure giving details of courses in Electrical Engineering and Electronics, covering A.M.Brit.I.R.E., City and Guilds, etc. Train with the Postal Training College operated by an Industrial Organisation. Moderate fees. E.M.I. Institutes, Postal Division, Dept. E.E.29, 43 Grove Park Road, London, W.4. Chiswick 4417 (Associate of H.M.V.). W 2338

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

PATENTS

NOTICE is hereby given that Electrical & Musical Industries Limited seek leave to amend the Complete Specification of the Application for Letters Patent No. 669419 for an invention entitled Improvements relating to the scanning circuit arrangements for television and like apparatus. Particulars of the proposed amendments were set forth in the Official Journal (Patents) No. 3,300 dated 14th May, 1952. Any person may give Notice of Opposition to the amendment by leaving Patents Form No. 36 at the Patent Office, 25 Southampton Buildings, London, W.C.2. on or before 14th June, 1952. J. L. Blake, Comptroller-General. W 1491.

ADVANCE COMPONENTS LTD., BACK ROAD, SHERNHALL STREET, LONDON, E.17 *Telephone : LARkswood 4366/7/8*

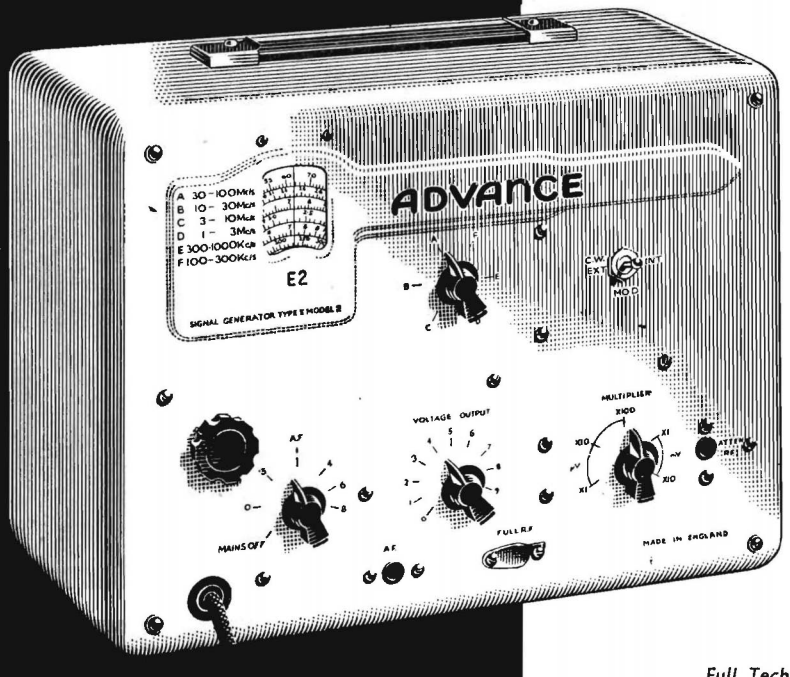
Modern in conception, design and performance, the E.2., with its exceptionally wide range, not only fulfils to-day's needs of radio and television, but anticipates the requirements of tomorrow. More than ordinary care has been used in screening and filtering. As a result, stray field is less than 3 μV. at 100 Mc/s.

● ***Frequency accuracy of ± 1% extends over the whole range.*** ● ***Output voltage 1 μV. to 100mv. and approx. 1v. at full R.F. Socket.*** ● ***Internal modulation; external modulation to 80%*** ● ***A.F. Output variable 0-50v. at 400c/s.*** ● ***Size 13" × 10¼" × 8".*** ● ***Weight 17½ lbs.***

Advance signal generator

ADVANCE TYPE E2

100 Kc/s – 100 Mc/s ON FUNDAMENTALS

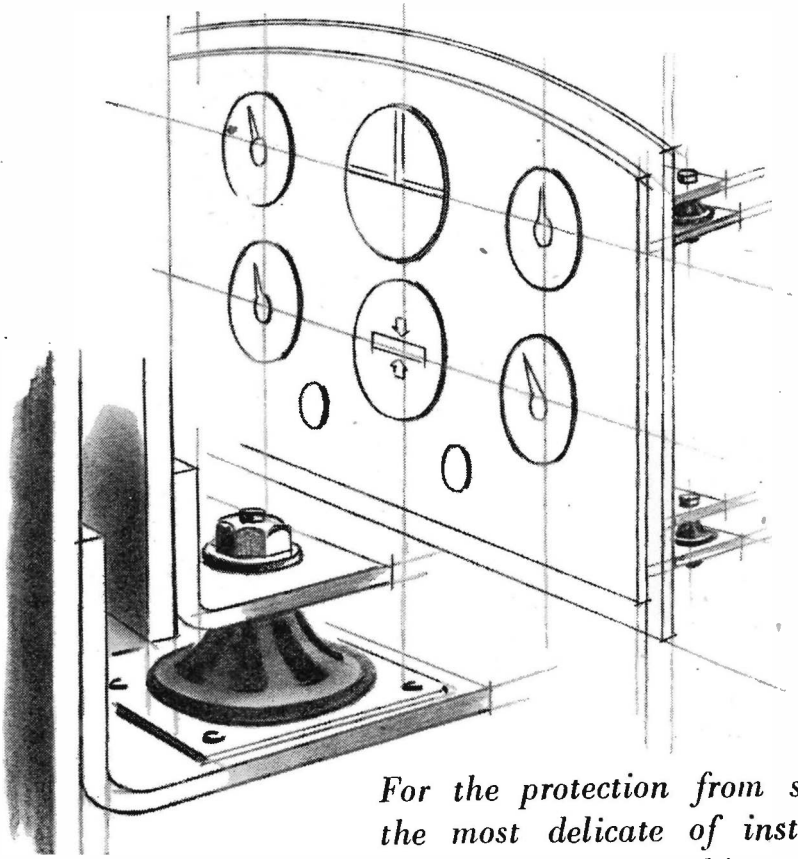


Full Technical Details available in Folder S/14/L

ADVANCE COMPONENTS LTD., BACK ROAD, SHERNHALL STREET, LONDON, E.17 *Telephone : LARkswood 4366/7/8*

This is the function of a

"FLEXILANT" MOUNTING



For the protection from shock of the most delicate of instruments and of panels which are subject to vibration, this range of "Flexilant" light mountings is at your service. Have you any problems where we could help?

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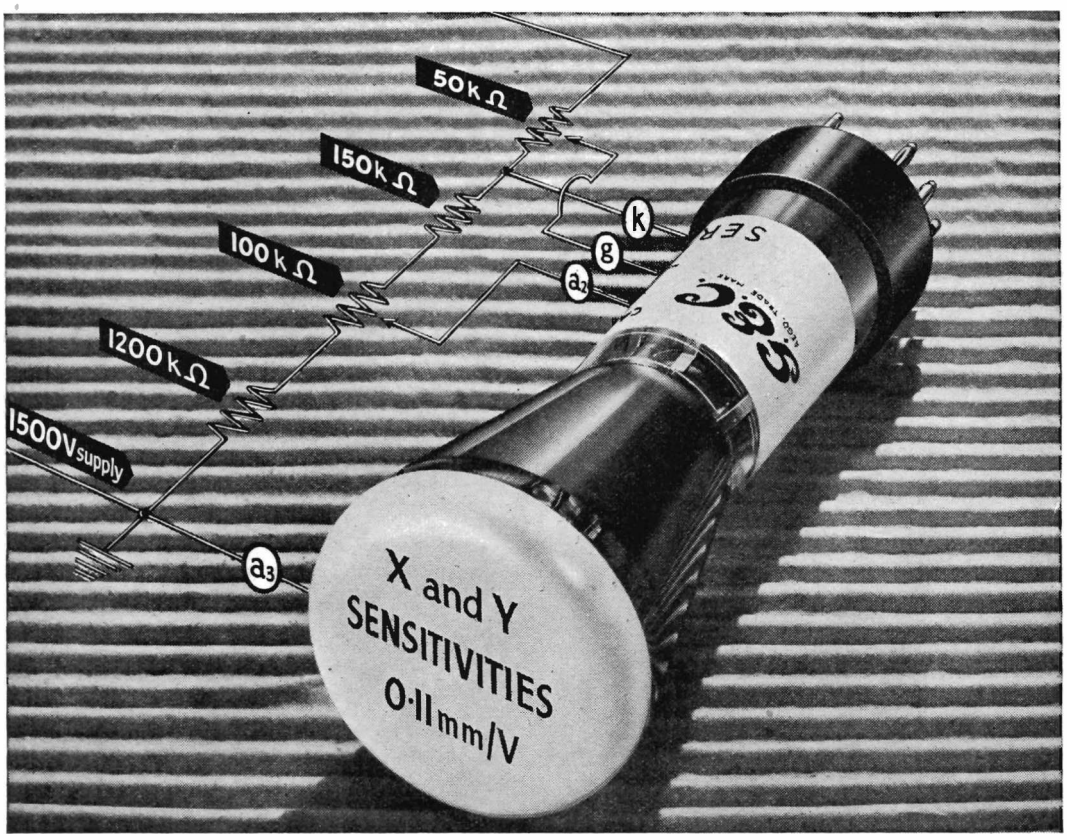
R.B. 81



G.E.C. instrument cathode ray tubes

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

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

Special screens are available to order.

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

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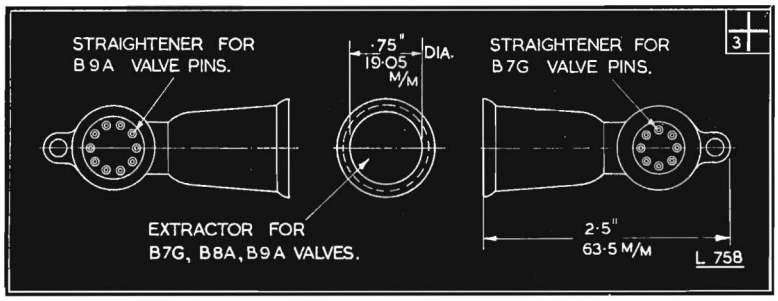
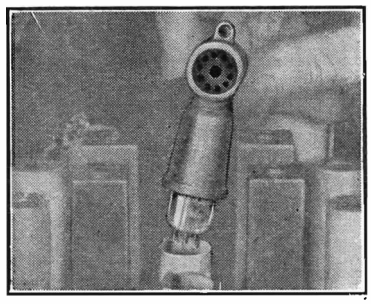
The "Belling-Lee" page for Engineers



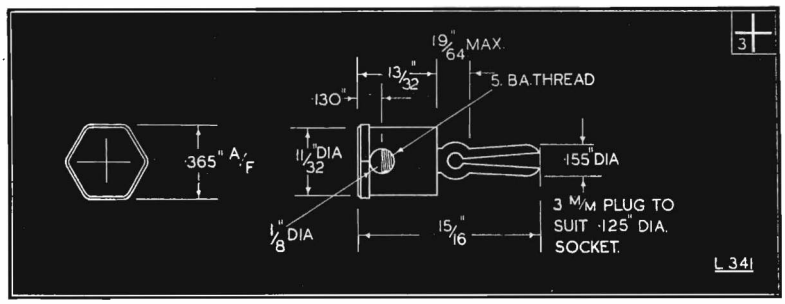


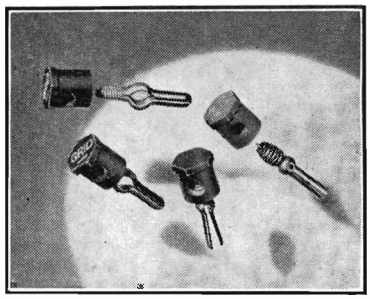
VALVE EXTRACTOR

LIST NUMBER
L 758

Suitable for B7G, B8A, and B9A valves, this novel valve extractor will be found extremely useful for removing valves from equipment made up of closely packed components.

The extractor is moulded in rubber, and a pin straightener for B7G and B9A valves is incorporated in the handle. This is accurately moulded in a hard phenolic material; and will obviate the damage to valves and/or holders caused through trying to force insertion with bent pins.





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LIST NUMBER
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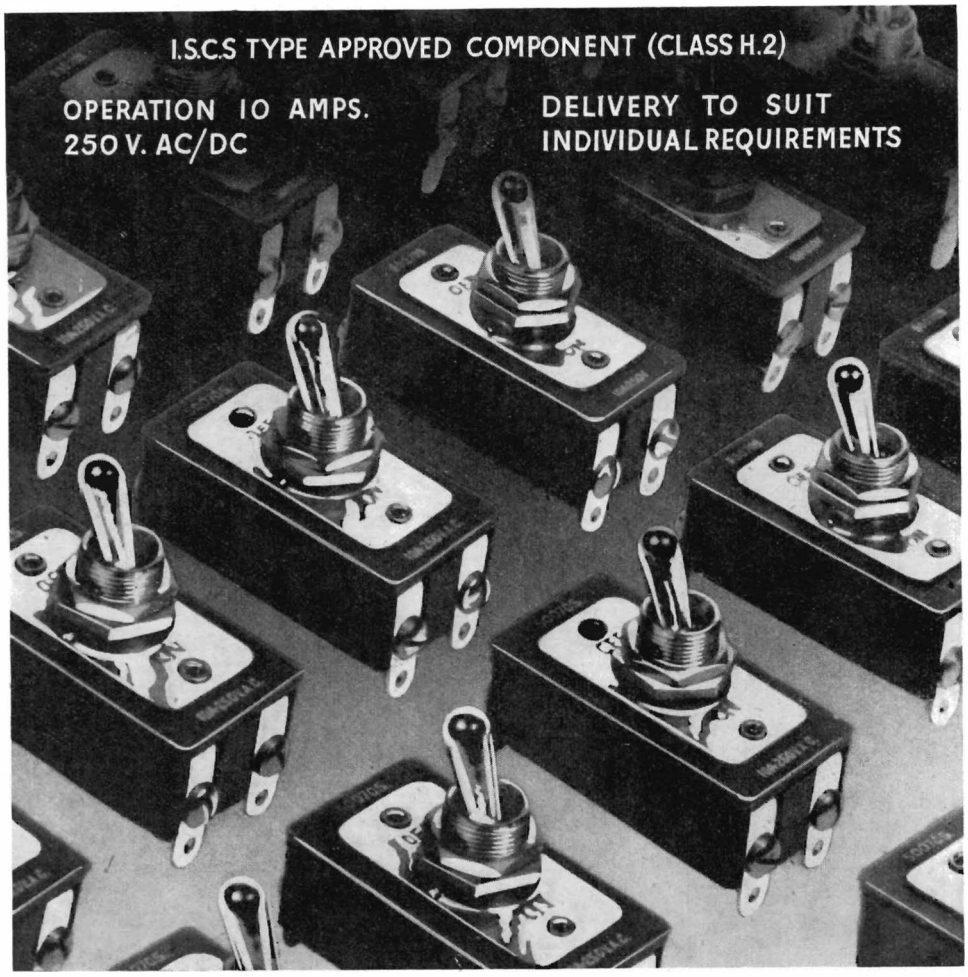

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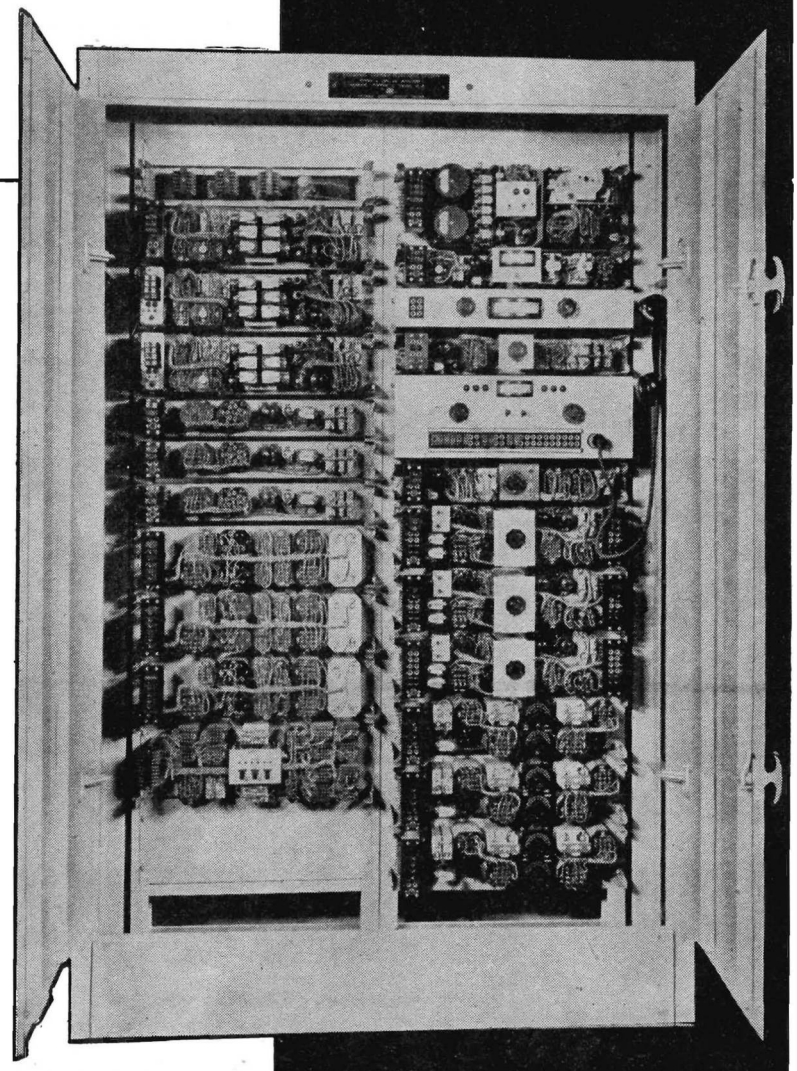

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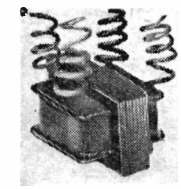
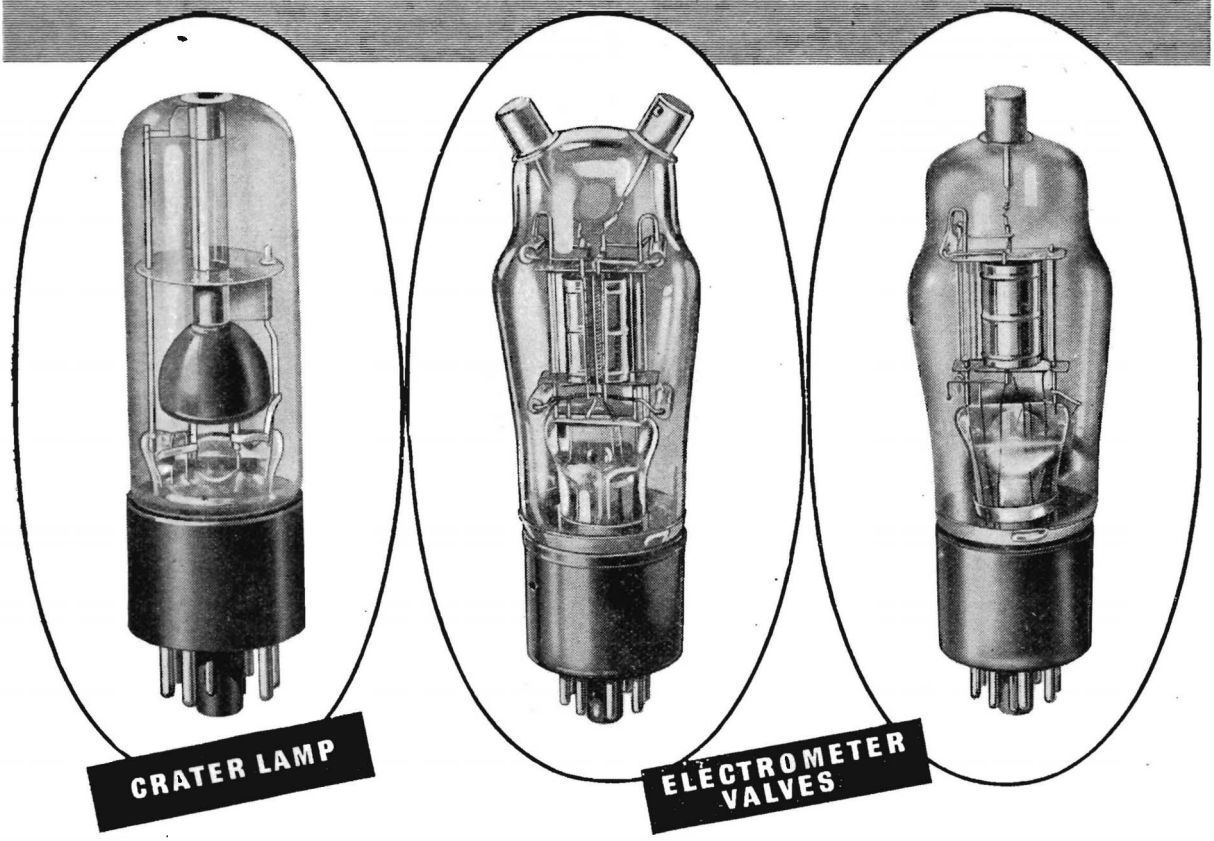


3 industrial valves from a large range



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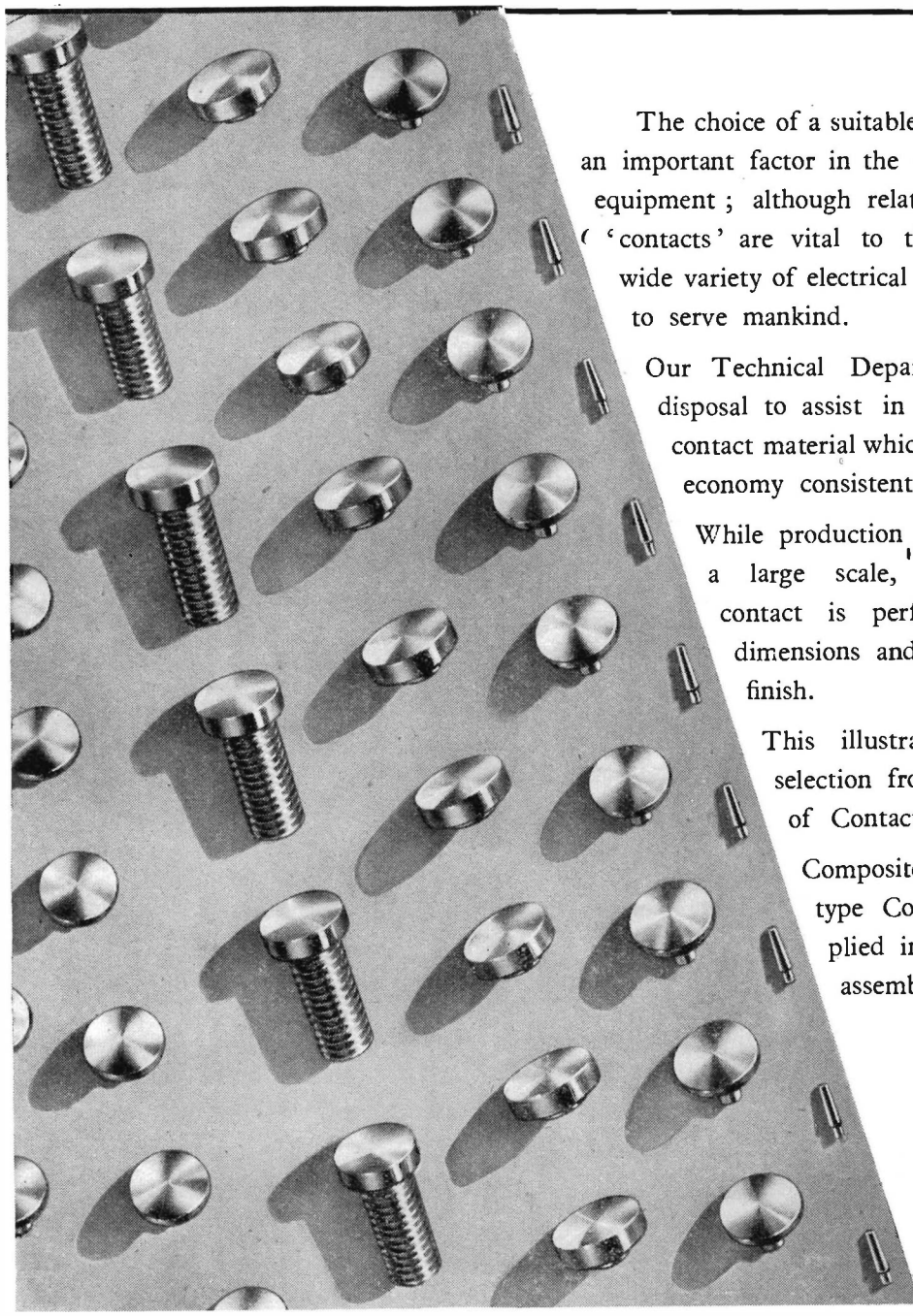

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Photo by courtesy of Messrs. C. A. Parsons & Co. Ltd.

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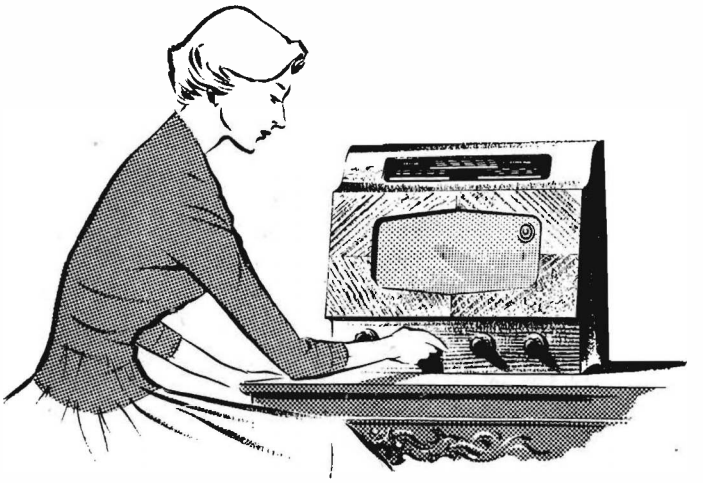

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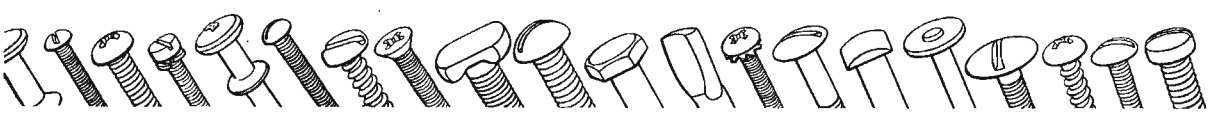

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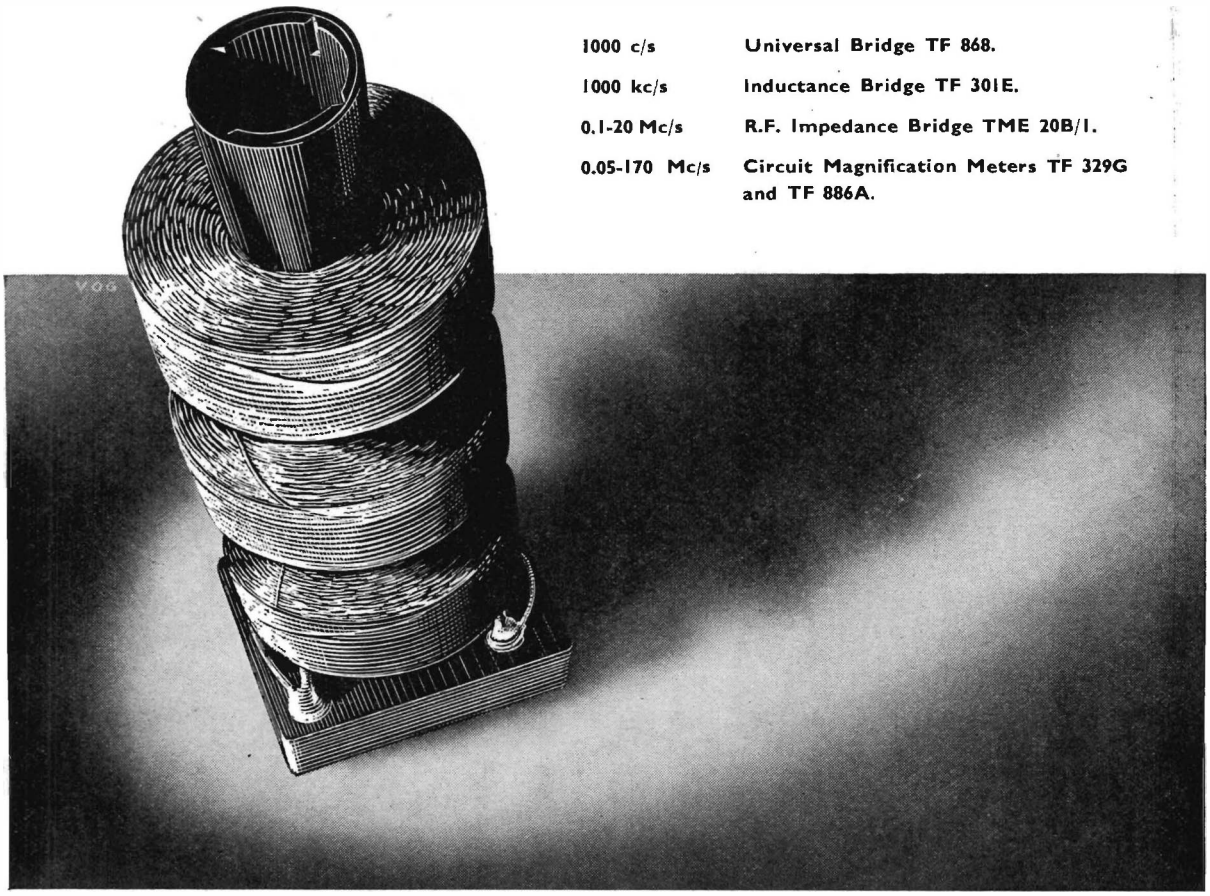

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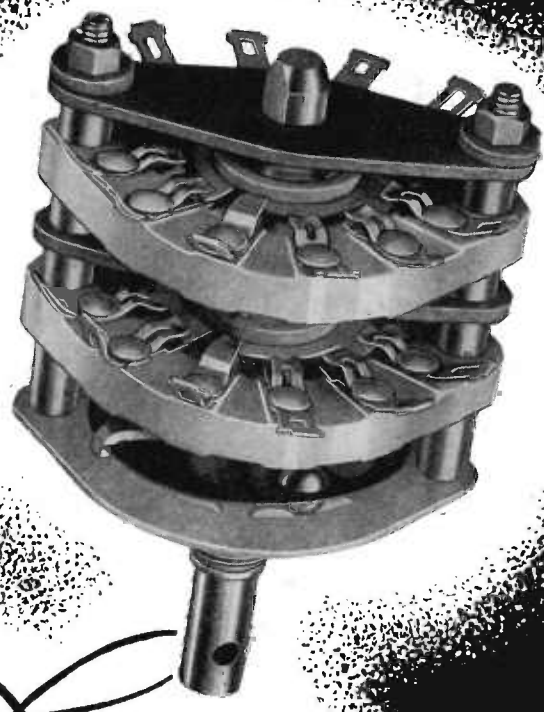

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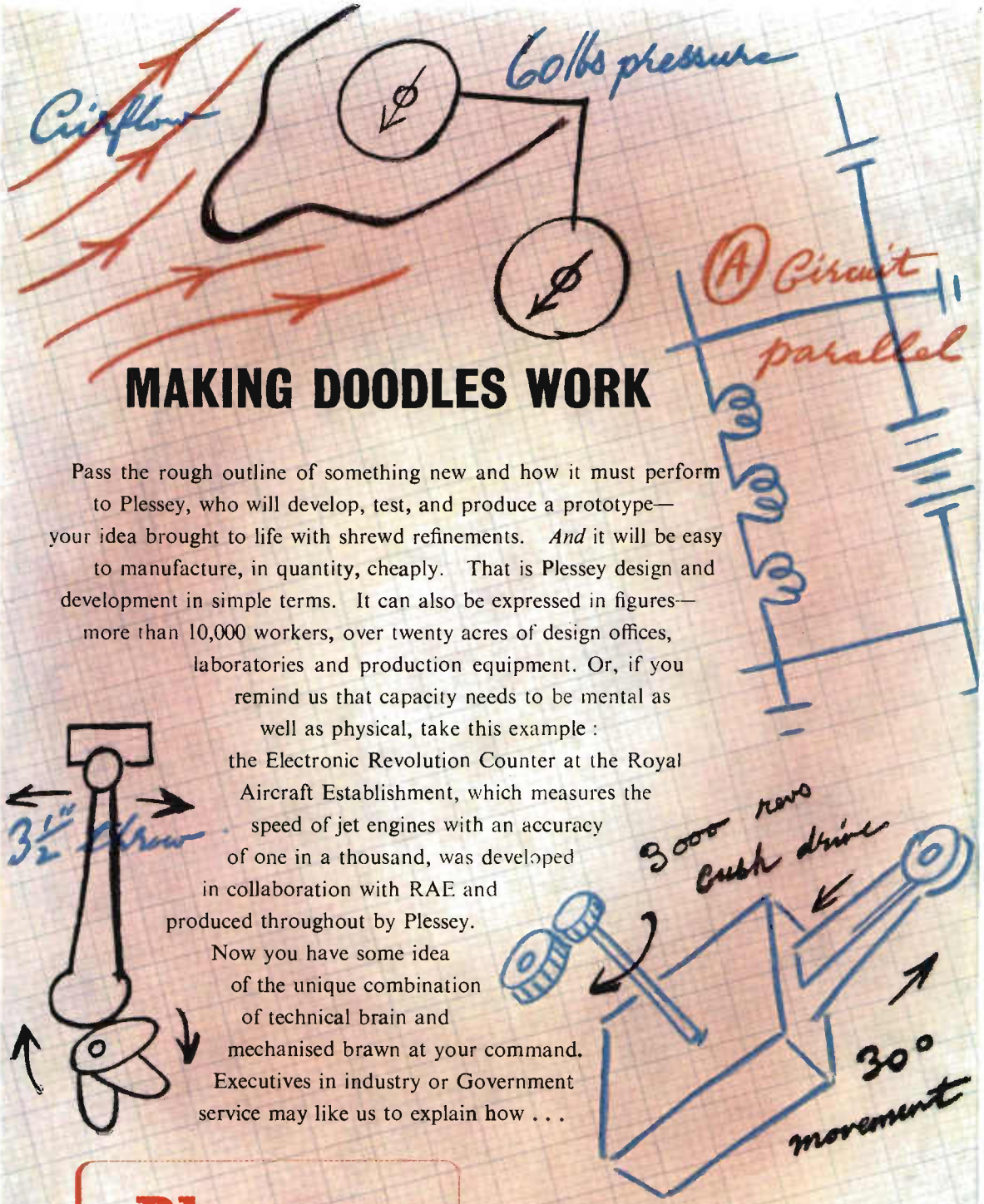

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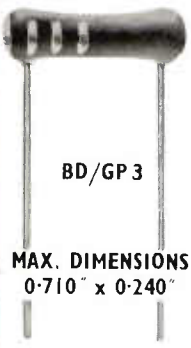 BD/GP 3 MAX. DIMENSIONS 0·710" x 0·240"	2001 to 5000 mmfd (0·005 MFD)

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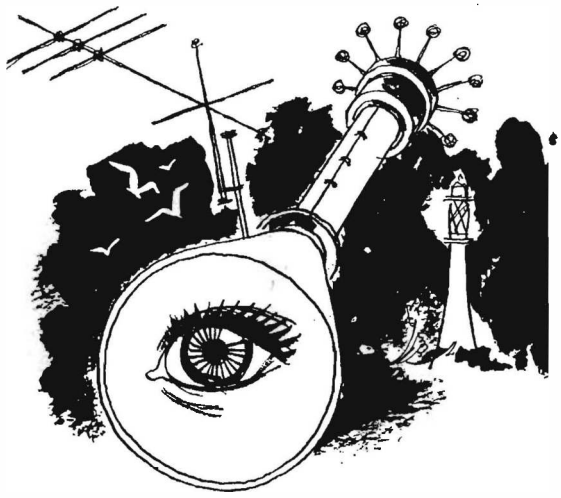

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Vol. XXIV JUNE 1952 No. 292

Contents

Commentary	257
An Automatic Circuit Checker ... ... By V. J. Cox	258
The Aerial Mixing Circuit at Daventry	263
Matric Theory Applied to Thermionic Valve Circuits ... ... By Sidney R. Deards	264
Audio Frequency Spectrum Analysis (Part 1) ... By S. V. Soanes, M.A., Ph.D., Assoc.Brit.I.R.E.	268
Some New Multivibrators ... ... By Lt.-Col. Chang Sing, B.Sc., and Capt. Chu Yao-I, B.Sc.	270
Some Recently Developed Cold Cathode Glow Discharge Tubes and Associated Circuits (Part 3) ... By G. H. Hough, Ph.D. and D. S. Ridler	272
A Direct Reading Mains Frequency Cycle Counter By P. Huggins, A.M.Brit.I.R.E.	276
A New Radio Telescope	277
Peak-Noise Characteristics of Glow-Discharge Voltage-Regulator Tubes ... ... By H. Bache, B.Eng., and F. A. Benson, M.Eng., A.M.I.E.E., M.I.R.E.	278
Feedback in Time-Base Circuits ... ... By A. E. Ferguson, M.E.E., A.M.I.E.Aust.	280
The Anodic Oxidation of Aluminium ... ... By G. C. Thompson	281
Radio Beacons for Lighthouses and Light Vessels	283
A Simple Capacitance-Meter ... ... By V. H. Attree, B.Sc.	284
Millimicrosecond Pulse Techniques (Part 2) ... By N. F. Moody, A.M.I.E.E., and G. J. R. McLusky, B.Sc.	287
Millimicrosecond Pulse Techniques (Part 3) ... By N. F. Moody, A.M.I E.E.	289
Letters to the Editor	295
Book Reviews	296
Electronic Equipment	298
Notes from the Industry	300
Publications Received	300

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Classified Advertisements, Page 1
Index to ADVERTISERS, 56

A Range of Thyratrons for Static and Mobile Applications

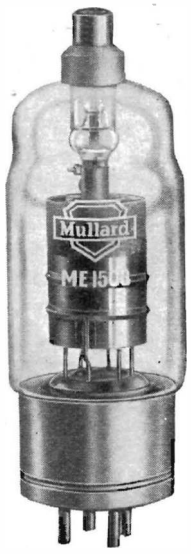
The Mullard range of thyratrons now includes types suitable for use in both static and mobile applications.

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

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

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

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



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

** Supplies temporarily restricted to Government Contractors only.*

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MVT 113

Electronic Engineering

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Commentary

"THE mixture as before" might well be applied to the memorandum on the Report of the Broadcasting Committee, 1949, which has just been issued as a White Paper (H.M.S.O. Cmd. 8550, Price 6d.).

As we are all aware, the charter granted to the British Broadcasting Corporation on January 1, 1947, expired at the end of last year and the present Government decided that in order to allow more time for consideration of a new charter of a more permanent nature, an interim charter should be granted for six months. During this time the Government would have time to ponder on the recommendations of the Beveridge Committee and to take into account the proposals put forward by their predecessors.

Since, happily, it was decided not to make it a party political issue, it is not surprising that the present White Paper breaks no new ground and that the major issues have been settled very much as anticipated.

The prescription is in effect pretty much as before, for while the monopoly of the B.B.C. has been maintained, there is at least a hope that sponsored television programmes may appear when, but only when, the present limitations on capital expenditure allow.

Unlike conditions in sound broadcasting, the production costs of television are far in excess of income as represented by the licence fee and it is admitted that unless the present fee is increased some other form of revenue must be found. How far sponsoring would assist in this direction has not been made clear by the Government who have decided that sponsored television cannot take place on the existing B.B.C. channels and it must wait until conditions improve and a channel on the higher frequencies made available. While we are not necessarily in favour of sponsored television, we should have liked to have seen the reasons stated why the existing dead period before the main evening programme could not be utilized—at least for an experimental period.

In drawing up the new Ten Year Charter to come into operation on July 1 this year, the Government have decided, wisely we think, to allow the B.B.C. to continue in its present form and that if an adequate national coverage is to be provided for both sound and television, the B.B.C. must have first claim on labour and materials when these become available.

Rearmament and the consequent limitations of capital expenditure account for the almost summary dismissal of the subject of V.H.F. broadcasting, although it is announced that an advisory committee will be asked "to consider the best methods of introducing higher frequency sound broadcasting into the system in this country, including the form of modulation to be adopted, on which consultation with the radio industry will be essential."

Two recent events of historical interest should not be allowed to pass without comment, since each in its way is a milestone in the growth and development of the radio and its allied industries. They were the Silver Jubilee of the Television Society on April 25th and the coming of age of the Radio Industries Club on May 20.

The Television Society was founded in 1927 following J. L. Baird's demonstration of his television system to the British Association for the Advancement of Science at their annual meeting at Leeds and we should like to offer our congratulations to this enthusiastic body of pioneers.

To many of us, particularly those who have only made acquaintance with television in the post-war years, twenty-five years of television seems a remarkably long time and only last month was it possible to go back twenty-five years and see what it was which first roused our enthusiasm. One of the most outstanding episodes of the Institution of Electrical Engineers Convention on the British contribution to television was the working demonstration of a complete Baird 30-line system in the 1927 style.

The Radio Industries Club originated in a luncheon held on May 20, 1931, to explore the possibilities of forming a Social Club which might make for closer co-operation between all sections of the industry, and here again we must offer our congratulations to the Club on reaching its majority and for the successful way it has, over the period of years, achieved its major object in promoting "mutual understanding and good will among those engaged in the radio and allied industries."

In those twenty-one years the growth of the radio industry cannot be better demonstrated than by the following table:

	1931	1952
B.B.C. licences ..	4,300,000	12,500,000
Licence income ..	£1,180,000	£12,100,000
Broadcast programmes	8 (Domestic services only)	Total of 56 including European and overseas programmes
B.B.C. transmitters ..	21 (Total power 160 kW)	54 (Total power 1953 kW)
B.B.C. employees ..	1,230	12,500
Employees in the radio industry	18,000	95,000
Annual value of radio products :—		
Home (ex works) ..	£8,800,000	£68,000,000
Exports (f.o.b.) ..	£1,003,000	£22,700,000
Television sets ..	Nil	700,000 in 1951

An Automatic Circuit Checker for Radio Receivers

By V. J. Cox *

This instrument is designed to check automatically, at high speed, the circuit wiring and components of radio receivers and similar apparatus on the production line. Receivers with incorrect wiring and faulty components are rejected with the faults so localized and specified that they may be easily diagnosed and corrected by comparatively unskilled personnel. By checking all receivers from the assembly line on the instrument before they are passed through the normal alignment and calibration test stages, the percentage of rejects at these subsequent test points can be kept very low and the average testing time per unit reduced proportionately.

THE method of checking the wiring and components of receivers is briefly as follows:—

A standard receiver, known to be correctly wired and having components selected so that the resistance, capacitance and inductance values are in the middle of the required tolerance range, is plugged into the standard side of the auto-checker through a group of cables that make contact with all accessible points on the receiver such as valve holders, connecting plugs and sockets. As receivers of the same type come off the assembly line they are connected to the test side of the auto-checker through a similar group of cables terminating in valve adaptors and connecting plugs and sockets. When the "start" button on the tester is pressed, a series of uniselector switches operate to connect, successively and momentarily, comparable circuits in each receiver to the test and standard arms of a Wheatstone bridge. The D.C. resistance and A.C. impedance to chassis and/or H.T. line from each valve or plug pin in the receiver under test is compared in the bridge network with the same circuit in the standard receiver. The detector of the bridge is followed by a trigger circuit which operates to switch the selectors on to the next circuit only if the "out-of-balance" voltage at the detector comes below a predetermined level which is related to the tolerance limits to which the auto-checker has been adjusted.

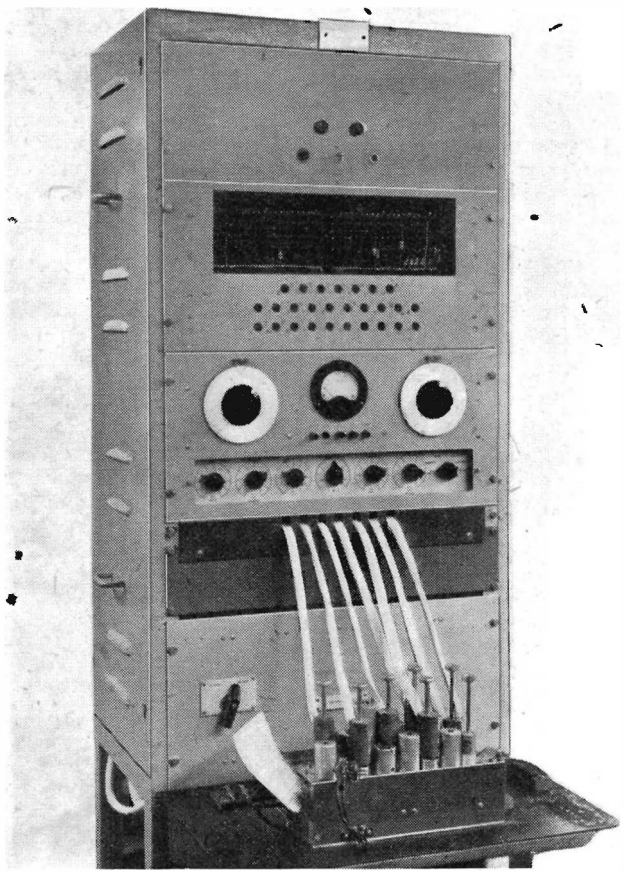


Fig. 1. The complete instrument

If the circuit under test is outside the tolerance limits, the auto-checker stops and the valve and pin number is given by indicator lamps on the front panel. The operator then presses in turn the "Hand AC" and "Hand DC" buttons on the front panel and by means of two calibrated controls and a meter as null indicator, determines the exact percentage out-of-balance of the A.C. impedance and D.C. resistance of the fautly circuit. Having noted the circuit reference and the percentage error, the auto-checker is restarted by again pressing the "start" button. All faults are noted in a similar manner, and on completion of the checks, the accumulated data enables all the faults to be easily diagnosed and rectified. The test automatically comes to rest at the "start" position ready for the next receiver when the sequence of tests is completed. Should it be desired to return to the start at any time during the course of the checks, this may be readily accomplished by pressing the "home" button.

When the "start" button is pressed at the beginning of the test, the auto-checker runs through a series of limit check points before starting on the impedance test proper, the selectors being connected in turn to specially selected resistors which have values just inside and outside the high and low percentage limits to which the test has been adjusted. At the same time corresponding indicator lamps on the front panel of the selector unit are illuminated.

The test should pass the "High in" and "Low in" checks on both A.C. and D.C. and should stop at "High out" and "Low out" on both A.C. and D.C.

With the standard type of selector unit, up to 150 impedances or circuits may be checked.

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

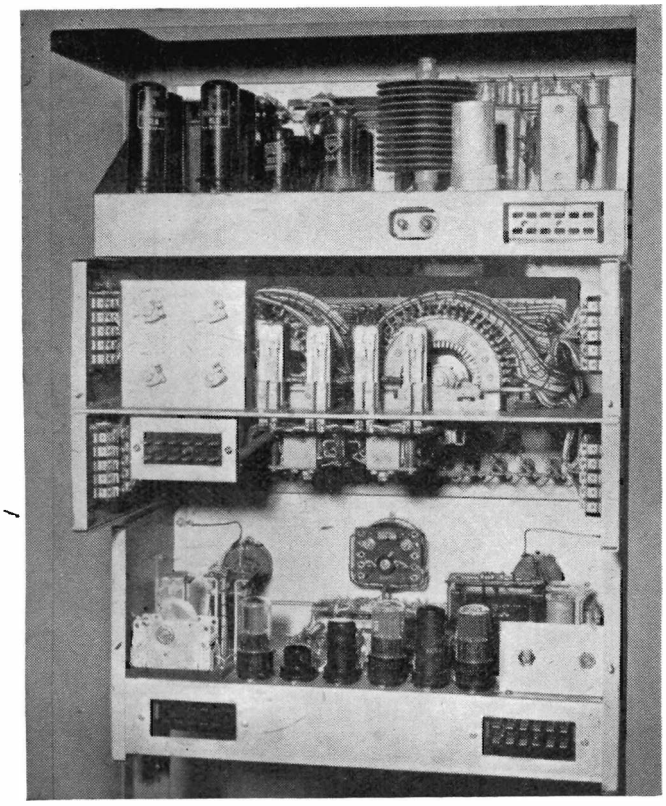


Fig. 2. A rear view of the complete instrument

Should the number of points to be tested be less than the maximum number, the unused pins on the selector panel connecting plugs are left blank on both the test and standard sides. The selectors will then pass through these points without stopping.

Each circuit is checked automatically twice, first with 50V D.C. input to the bridge and then with 3V at 120c/s, and 3V at 1,000c/s simultaneously. The two tests, one for D.C. resistance and the other for A.C. impedance are made in order to make the check as comprehensive as possible. Obviously if the circuit under test contains just capacitance, or any series combinations of L, C and R, a D.C. test can only detect shorted capacitors, and shunt combinations of L, C and R cannot be compared correctly with D.C. only applied to the bridge as far as reactive components are concerned. Similarly if the tests are carried out at A.C. only, even moderately high value resistors shunted by capacitances or inductances will not be checked accurately. By first subjecting every circuit to a true D.C. test this possibility of error can be avoided and an accurate resistance test can be made.

The complete auto-checker consists of four 19-in. rack panels and occupies a total rack space of 33¼in. Starting from the lowest panel they are: standard receiver, auto bridge unit, selector unit and power supply unit. Fig. 1 shows a front view of the instrument as set up for testing a television R.F. unit. Inspection covers have been removed to show preset controls and the 150 way tag boards.

A rear view is shown in Fig. 2, the units proceeding from top to bottom, being: power unit, selector unit and bridge unit.

The power supply unit provides the following regulated outputs:—

300 volts 80mA positive
50 volts 80mA positive
85 volts 2mA. negative
also 24 volts 2 amps D.C.
20 volts 1 amp A.C.
6·3 volts 2 amps A.C.

The three regulated supplies are used respectively for auto bridge supply, power supply for D.C. bridge, and trigger circuit bias. The 20 and 24 volt supplies are used in the selector unit for pilot lamps and uniselector coils, while the 6·3 volt supply provides heater current for the auto bridge.

The 300 volt supply is obtained from a standard series-valve voltage regulator and is compensated for both mains voltage and load current variations. The actual regulation with 200-270 volts mains input variation and 0-160mA load current is better than plus or minus 0·5 volts.

The 50 volt bridge supply is obtained from a similar circuit fed from the 300 volt regulated output.

As the drain on the 85V regulated bias supply is small, a simple neon stabilizer is used fed from a metal rectifier. This supply is also used for control valve bias on the 50 volt bridge line.

The bridge unit contains all the components actually associated with impedance checking except the standard impedance which for set testing must be varied from one check point to the next. Although all components are on one chassis, and in some cases the same component is put to different uses in the various modes of operation on the bridge, it will be convenient for the purposes of explanation to split the unit up into four sections, namely:—

1. Oscillator.
2. A.C. discriminator.
3. D.C. discriminator.
4. Trigger circuit.

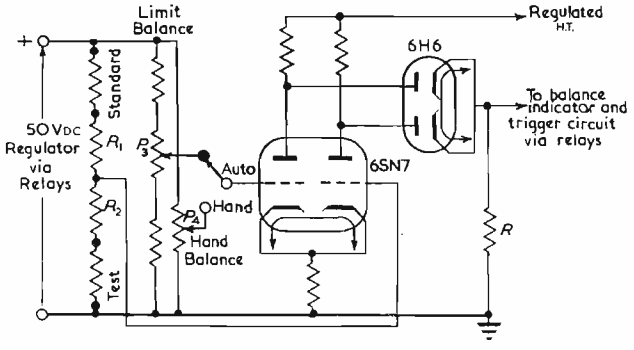
Oscillator (Fig. 3)

This consists of a medium-impedance double-triode valve type 6SN7GT, with each section acting as a resistance-stabilized Hartley oscillator at frequencies of 120c/s and 1,000c/s respectively. These two frequencies are fed to the grid of a 6V6 which, via an output transformer, supplies A.C. power to the bridge. Due to the design of the bridge network a screened and balanced transformer is not required in this application.

A.C. Discriminator (Fig. 4)

The oscillator output is fed to the bridge network via the A.C./D.C. change-over relay. The network is a true bridge circuit but is not balanced to ground. It will be seen from the circuit that should P_1 be set so that there is an equal resistance from each side of the oscillator to the cathode of the 6AC7 there will be a state of balance between grid and cathode when both "standard" and "test" are equal. Should the test impedance differ from the standard, an out-of-balance voltage will be produced, Actually, for test errors of plus and minus 30 per cent out-of-balance voltages of plus 6·5 per cent and minus 8·8 per cent of the oscillator voltage will be produced. If the bridge were left in its present state it is obvious that the

Fig. 3. Oscillator circuit



high and low limits of the following amplifier and trigger circuits would differ, so a limit balance control (P_1) is incorporated. By off-setting this control, equal out-of-balance voltages for plus and minus limits may be obtained. It is important to note that the setting of this control only holds good for one particular percentage limit, but as set testing is normally done on fixed limits, this does not affect the accuracy of the check.

Some special cases, however, will arise with wide tolerance components such as by-pass capacitors. If for

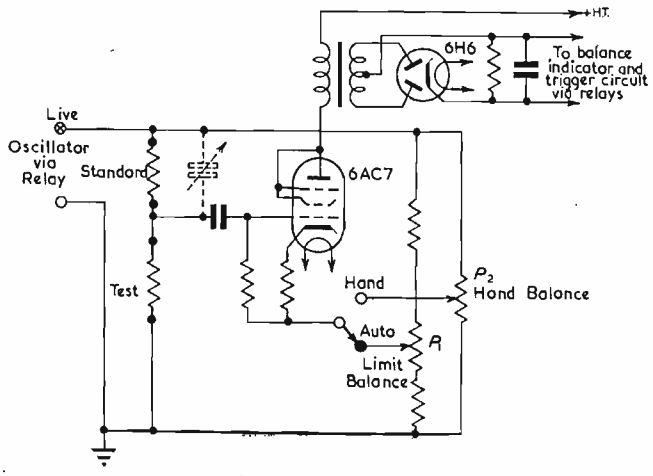


Fig. 4. A.C. bridge and discriminator

example a $1\mu F$ capacitor has a tolerance of ± 60 per cent the bridge limits may be widened to cover this by shunting both "test" and "standard" arms with two standard $1\mu F$ capacitors, then the ± 60 per cent tolerance on the test capacitor will appear to the bridge as ± 30 per cent of $2\mu F$. Provision for the connexion of these limit-correcting impedances is made on the uniselector panel in the form of two 150-way tag blocks mounted behind the front panel. Although all standard and test points are brought out to these tag blocks it is rarely necessary to shunt more than five or six contacts.

By switching the 6AC7 cathode from the balance control (P_1) to the hand balance control (P_2) the bridge may be balanced manually for any condition of test and standard. Since the limit-balance and hand-balance controls are of low impedance (10 and 50 ohms respectively) the cathode output impedance has a negligible effect on balance. A transformer input to the 6AC7 grid could not have been used in this case as the primary impedance (unless of improbably high inductance) would have seriously reduced the out-of-balance voltage at high test and standard impedance. As it is, the effective test shunting effect of the 6AC7 grid impedance is of the order of 30 megohms which for component values used in normal radio sets can be neglected.

It will be seen that there is no correction for power factor in this circuit but in practice this is not found necessary, as, although the power factor control may make a large percentage difference to the residual voltage with the bridge balanced, at 30 per cent out-of-balance the power factor differences met with in normal use, form a very small fraction of this voltage. The one case where it is of importance is catered for by a capacitance trimmer in the bridge unit connected between the live side of the oscillator and the 6AC7 grid. This case occurs in testing a blank connexion in the set. Under such conditions the bridge balance is determined entirely by stray wiring capacitances. Since the bridge is earthed only on the "Test" side, the capacitances here must inevitably be greater than across the "standard" arm. To compensate for this the trimmer is adjusted in calibration to equal the average wiring capacitance of the leads in the selector panel and jig, in addition, care is taken to ensure that the leads in the selector panel shall have, as far as it is practicable, identical capacitances to earth. In this connexion it is important to note that while cable forms have given no trouble in this respect, they should be spaced from the chassis to prevent high capacitance to earth.

The grid-to-cathode input of the 6AC7 is amplified in the normal way by the valve and is applied via a transformer to a full-wave diode rectifier. The transformer has an advantage over resistance coupling in that it provides a low source impedance for the diode thus ensuring a short time of rise for out-of-balance voltage. Since rising volts at this point prevent the trigger operating the selectors when the test is out of limits care must be exercised to prevent it becoming a limiting factor in the speed of testing.

The only other point of interest in this circuit is the use of two frequencies simultaneously for the bridge supply. It may be seen from the circuit that since the oscillator voltage is applied directly across the series impedance of "Test" and "Standard", if the regulation of the oscillator is perfect, out-of-balance voltage will be produced from zero impedance up to the point where the input impedance starts seriously to shunt the bridge and affect the percentage limit setting, i.e., about 5 megohms. Unfortunately, another effect has to be considered. If, in a set under test, a capacitance of 1,000pF shunted by 1 megohm is to be measured; at an oscillator frequency of 100c/s the 1·5 megohm reactance of the capacitor, heavily shunted by the 1 megohm resistor, will not be checked with any great degree of accuracy. At 1,000c/s however, the capacitor will be checked with an accuracy 10 times as great. Since the opposite effect occurs with inductance shunted by resistance, or capacitance in series with resistance, it can be seen that both frequencies have advantages for different conditions of test.

One obvious solution is to test first with one frequency then the other, but in view of the extra operating time and comparatively few additional faults the extra cycle would bring to light, this solution was rejected. As a compromise the method of mixing the two frequencies was adopted, and this, while not being as good as separately testing on each frequency, is a worthwhile improvement on single-frequency testing.

D.C. Discriminator (Fig. 5)

The bridge supply in this case is obtained from the 50V 80mA regulated supply from the power unit. The figure

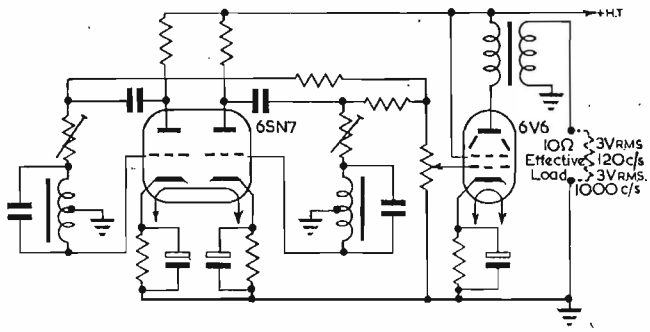


Fig. 5. D.C. discriminator

of 50 volts was chosen as the lowest regulated supply voltage conveniently obtainable. As with the A.C. discriminator, the supply is applied directly across standard and test arms and provision is also made for limit-balance and hand-balance controls. R_1 and R_2 are two limiting resistors of low value necessary to limit the current consumption of the bridge on short-circuit (earth) tests. These resistors limit the current to the permissible 80mA which

is the maximum the single 6L6 series regulator valve will deliver. It would be possible to parallel several 6L6's to increase the available current, but then the possibility would occur of the bridge stopping on a low wattage resistor and damaging it. As it is, the maximum wattage that any test resistor may be loaded to by the bridge is ½W which, for all practical purposes, is adequately small.

At first sight, it would seem that R_1 and R_2 could be replaced by a single resistor of twice the value in the 50V positive lead; but in fact, due to the nature of the following discriminator circuits it is necessary to place them between the two selector arms and match them accurately to prevent false out-of-balance voltages with low values of test resistance. The effect of these resistors is to widen the percentage limits when testing resistances of below 1,500 ohms approximately. Since the A.C. discriminator can deal with impedance down to 20 ohms and, with increased limits, down to 1 ohm, this is not a matter of great importance.

The discriminator itself is based on a cathode-coupled phase invertor. This circuit has the property of reproducing changes of voltage at either grid in amplified form at both anodes. Also the circuit is effective at zero frequency and the voltage changes at the two anodes are of opposite polarity.

This circuit has been described before on several occasions; briefly, a positive voltage on the grid of one valve would cause the two cathodes (which are strapped together) to move positive and its own anode to move negative. Since the grid of the second valve is held at some fixed potential the effect of its cathode moving positive is to drive its anode positive. As the circuit is symmetrical it will be seen that this mechanism holds good for an input to either grid, and also both grids simultaneously.

Considering the circuit as a whole, if equal resistances are connected across the standard and test arms and the limit-balance control (P_3) is set at the centre of its track, each of the grids of the 6SN7 will be held at half the D.C. supply voltage, i.e., 25V positive. That being so, and if the triode sections of the valve and their associated components are perfectly matched, each anode will be at the same potential, approximately 150V positive to earth. Both diodes will then be conducting and the load resistor R will be held at the same potential.

If the test resistance is reduced, the voltage on the second grid will fall, causing its anode to rise and the first anode to fall. The diode cathode will take up the potential of the higher voltage anode (No. 2 anode), the current flowing through the load resistor thus biasing the other diode to cut-off.

If the test resistance is increased, the same voltage changes will be produced at the anodes but this time with opposite polarity. The diode cathode will still follow the rise of the higher potential anode. It will be seen that for a percentage increase or decrease of test resistance a positive out-of-balance voltage will be produced at the cathode of the diode and that the lowest voltage produced there will correspond with zero percentage out-of-balance.

If the test resistance is reduced to such a value that the second grid is held at 24V instead of 25V an out-of-balance voltage will be produced, but if the first grid potential is increased by 1V the out-of-balance voltages will cancel out. Thus, P_4 is used as a hand-balance control and P_3 is used for limit-balancing, as previously explained, in the A.C. discriminator.

The Trigger Circuit (Fig. 6)

This comprises a D.C. coupled trigger circuit with two stable limiting conditions. The first D.C. coupling is via R_1 and R_2 to No. 2 grid and the second via the common cathode resistor.

R_x and R_y are returned to 90V D C. negative in order to provide correct bias potentials for the proper functioning of the circuits. With the values in use the circuit triggers (i.e., section 1 moves to cut-off and section 2 to saturation) when the first grid potential falls to 5V negative; R_3 is included to limit the current of section 2 to a safe value. To detrigger, the first grid must rise to about 10V positive, there is therefore 15V backlash between triggering and detriggering. If this triggering action were used to close the relay RS_1 and allow uniselectors to select circuits at some predetermined rate, unless the out-of-balance voltages were very large in comparison with the backlash of 15V, i.e., about 1,000V, this backlash would produce serious errors depending upon whether a circuit were tested on the upward or downward strokes. If, however, the trigger circuit is detriggered between each single test it will be seen that the backlash is of no importance since RS_1 must open between each circuit test and cannot close again unless the input voltage to the first grid is more negative than the critical value of 5V negative.

This detriggering action is easily provided by the uniselector self-drive contact. This contact is normally closed and mechanically connected to the armature of the uniselector and every time the armature is attracted to the magnet this contact opens. As will be seen from the circuit, this will apply a high positive potential to the first grid thus detriggering it. It should be noted that R_x and R_y do not exist in actual practice as they are automatically provided by the coupling arrangements from the discriminator circuits.

So far it has been assumed that when RS_1 is closed the uniselector will proceed at some predetermined rate; but

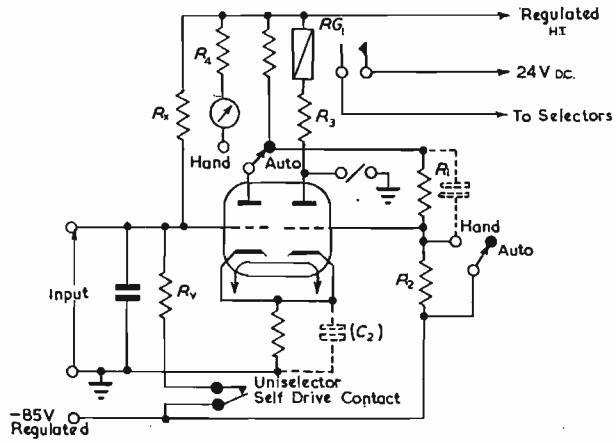


Fig. 6. Trigger circuit

it can now be seen that the trigger circuit itself can determine and control that rate. The action is as follows:—

The uniselector is at rest on "good" circuit; the final out-of-balance voltage at the trigger grid is therefore more negative than minus 5 volts. RS_1 closes, thus energizing the uniselector magnet which moves its ratchet pawl, also opening the self-drive contact. The opening of the self-drive contact drives the trigger grid highly positive, thus detriggering it and de-energizing the uniselector magnet. The armature returns to normal, the pawl then pulling the wiper arms round one contact and closing the self-drive contact. The heavy surge produced by the detrigger action renders the bridge inoperative in the reject condition for about 10 milliseconds; after this time it is free for triggering but only if the out-of-balance voltage is below the 5V negative trigger voltage.

If the circuit is left as it stands in the D.C. condition it will proceed at about 40 tests per second, and at 25 per second on A.C. The lower A.C. speed is due to the surge-retaining effect of the reservoir capacitor following the double diode rectifier. These speeds, while producing an awe-inspiring effect on the selector unit indicator lights, can only be of use on D.C. for checking pure resistance. If for example the circuit under test consists of a capaci-

tance in series with a resistance, during the short testing period (25msec) the capacitance will not have time to charge fully, thus presenting an impedance to the bridge, the value of which will depend upon the value of capacitance and the time and rate of charge. In other words the D.C. bridge is acting as a low frequency A.C. bridge.

In practice, with the time-constants encountered in normal sets it has been found satisfactory to place a capacitance between grid and earth on the trigger input, thus prolonging the detriggering surge and slowing down the rates to 10 and 15 contacts per second. These rates have been found satisfactory in production and, with a post-war set of average complexity, testing rates in excess of 200 sets per day have been reached. This includes time taken by the operator to connect and disconnect, also stop and restart times for checking switching operations, volume controls, etc.

There is one effect with this method of speed control which becomes apparent on hearing the gear in operation. After detriggering, the rate at which the voltage on the speed controlling capacitance falls will depend upon the residual out-of-balance voltage; the uniselector will therefore not move at a constant speed, but will stop for longer periods on circuits near the edge of the limits. This effect while avoidable by a different method of speed control, has been retained as a logical way of testing at the highest possible rate. There is no point in stopping on any contact longer than necessary to ensure that it is within limits, so long as sufficient testing time is allowed on D.C. to ensure a true D.C. check.

It will be seen that there are two capacitances C_1 and C_2 shown in broken lines. C_1 is a stray capacitance which is caused by various switch wiring. It will be seen that if this capacitance is sufficiently large, it will cause the circuit to act as a flip-flop or even to oscillate freely. To overcome this trouble C_2 ($0{\cdot}5\mu$F) has been shunted across the cathode, thus reducing the feedback at higher frequencies. At normal operating speeds this has no effect on the triggering action of the circuit and is a simpler remedy than carefully screening the offending leads.

The two switches on the circuit diagram, Fig. 6, are shown in the "auto" position and the circuit operation has been described in this condition. When the switches are in the "hand" position R_2 is short-circuited, thus applying 85V negative to the second grid and preventing *RS*, from closing. Also the first anode returns through a 5mA meter and a limiting resistor to H.T. positive. Since out-of-balance voltages are fed to the first grid by the action of the A.C. and D.C. discriminator it will be seen that this meter will act as a balance indicator.

When switching from "auto" to "hand", a voltage surge is produced which tends to detrigger the circuit, but on switching in the reverse direction, the surge will trigger it. If this is done in the middle of a testing sequence, there is a possibility that the uniselector will pass the following check point without an accurate test having been made. To overcome this trouble R_2 is also short-circuited on "hand" by a slugged relay, and the time which this takes to open on switching to "Auto" is sufficient to allow the bridge to settle down before recommencing testing.

The remaining switch on the diagram is the "Start" switch. It will be seen that when this is operated the relay will close whatever the condition of the bridge. It can thus be used for starting, restarting from a stop position or for stepping the uniselector round one contact at a time (with the bridge on "hand") for individual checking of circuits.

Selector Panel

This panel provides the means of switching the auto bridge to the various circuits under test. It consists of one master uniselector which does not in itself select the circuits, but controls slave uniselectors. There is space in the panel for up to three of these, each providing 50 circuits. The master uniselector, however, is not worked to full capacity and has sufficient spare positions to control further slaves up to a total of 400 contacts, which is more than adequate for any normal testing sequence. Up to the present, it has not been found necessary to use more than three slaves, giving 150 available tests.

The master uniselector has eight banks of 25 ways and the slaves four banks of 50 ways. With the selector panel in the "start" position, all uniselector wipers are on position 1 and a contact on the master uniselector keeps the bridge in the detriggered condition. When the "start" button is pressed and released this uniselector operates and passes through four standard check resistors just within and just outside the high and low percentage limits of the bridge. Should the bridge fail to stop on the outside limits, or stop on the inside limits, the operator then knows that the gear requires adjustment and can inform the maintenance engineer. Thus the possibility of passing a reject set through faulty limit-setting is greatly minimized. This procedure is repeated in both the A.C. and D.C. conditions.

Having passed through these test resistors the selector moves forward to a set of contacts which remove the driving and testing circuits from itself and transfer them to the first slave. This slave then runs through its 50 tests after which it returns the circuits to the master which moves on one contact, transferring the circuits to No. 2 slave.

As each slave returns the circuits to the master, it automatically returns itself to position 1, ready for the next sequence. This action proceeds until the last contact of the last slave is reached. The circuits are then returned to the master which runs through a series of blank contacts, at the same time operating a relay which changes the bridge from the D.C. to the A.C. condition. When this has been done, the slaves again run through the testing sequence, finally returning the circuits to the master which then homes itself to the start.

Should it be desired to discontinue testing a set, a homing circuit is incorporated which, when energized by a button on the bridge unit, allows the slave in use to return to position 1 under conditions of perfect bridge balance. When this position has been reached, if all other slaves are in position 1 (as they should be) it allows the master to home itself to the start. If for any reason the wiper arms on any of the uniselectors become misplaced, pressing the homing button will automatically return them all to the correct starting position.

The mechanical layout of the selector unit has been standardized for a maximum number of 3 slaves, giving 150 test points. This number can be reduced to either 50 or 100 by the addition of shorting links to the master selector. Intermediate steps of 25, 75 and 125 tests can be obtained, but this necessitates alterations to the wiper arms of the 50 way slave selectors and has not been found necessary as the extra time taken for the bridge to run through the additional 25 blank contacts has not formed an appreciable percentage of the total testing cycle.

The "test" and "standard" arm contacts are first linked to twin 150 way tag boards which are mounted behind, and accessible from, the front panel and then taken to two banks of 10 way plugs, the "standard" bank occupying the left-hand side of the chassis and the "test" the right-hand. The master selector has seven indicator lamps on the front panel, these lamps are marked respectively, left to right:—

A.C., (limit) Low in, High in, Start, (limit) Low out, High out, D.C.

Their functions are self explanatory. The valve-holders in most sets have between 5 and 10 available test points, so each plug has been allotted 10 contacts and each slave uniselector is connected to a common bank of lamps numbered pins 1-10. In addition each slave has five

individual lamps marked plugs 1-5; 6-10 and 11-15 respectively.

With this arrangement of 32 lamps the operator can see immediately, from the illuminated translucent figures, the condition of the bridge, A.C. or D.C., also the plug in use and the pin number of that plug.

In the general sequence of testing, the set under test normally has all the controls set to the maximum anti-clockwise position and all the circuits are D.C. tested in this condition. When this test is complete, link wires on the 150 way tag block route the following sequence of test positions back to circuits on the set under test which are affected by switching. The "standard" block, however, is wired in such a way as to require these controls to be placed in the maximum clockwise position in order to produce correct test conditions at the bridge. Consequently when the selector reaches the first retest position the controls on the set will be incorrectly positioned and it will stop. The operator now rotates the controls to the correct position and the selector will then restart. This procedure is repeated for all switch positions, thus checking every available circuit. After completing this the whole test is repeated on A.C.

Standard Receiver

This may be any production set whose component values have been selected to the required accuracy; but for reasons of neatness and accessibility the chassis is usually dispensed with and the individual components wired on tag strips mounted behind a standard 19in. rack panel.

For 30 per cent limits it has been found satisfactory to select components to a tolerance of plus or minus 2 per cent. There is one point to note in this connexion; the A.C. bridge measures percentage impedance and while this holds good for percentage inductance and resistance it is not correct for percentage capacitance. An example will make this point clear.

At a given frequency a capacitor has for example a reactance of 100 ohms. Therefore 130 per cent gives 130 ohms reactance which corresponds to $-23{\cdot}2$ per cent capacitance and 70 per cent gives 70 ohms reactance which corresponds to $+43$ per cent capacitance. It can be seen that a plus 30 per cent reactance will equal a minus 23 per cent capacitance and a minus 30 per cent reactance will equal a plus 43 per cent capacitance. If, however, the standard capacitance is selected to a mean $8{\cdot}5$ per cent below the standard capacitance value, the working limits will then be a true plus and minus 30 per cent.

Control Layout

All operating controls are on the bridge unit and consist of five press-buttons and two calibrated knobs. Three of the press-buttons are interlocked and marked respectively "Auto", "Hand A.C." and "Hand D.C." The remaining two are spring-loaded off and marked "Start" and "Home". These functions have already been explained.

The two calibrated knobs are "Hand balance" for A.C. and D.C. Each will cover from open-circuit to short-circuit test error, but is only calibrated over the range ± 50 per cent. The main use of these controls is not to determine accurately the percentage out-of-balance, but to discover whether the error is positive or negative for additional diagnosis data.

Mounted below these controls but behind a cover plate are the bridge setting controls. In addition to the four limit-setting controls a switch is provided to connect the meter to the various supply voltages to ensure that everything is normal before limit-setting. The last two positions of this switch connect the bridge to pairs of internal standard and test resistors which are calibrated over the range plus and minus 50 per cent, to simplify setting-up procedure. Thus the bridge may be set up on both A.C. and D.C. without reference to external standards.

Conclusion

Twelve auto checkers of this type have been in use for the past five years and have been found satisfactory both from the operational and maintenance points of view. Due to the self-calibrating nature of the gear, regular maintenance checks are not necessary. Since the bridge requires 10 to 15 minutes warming up from cold before it settles down, the gear is left switched on all day, irrespective of whether or not it is actually being used.

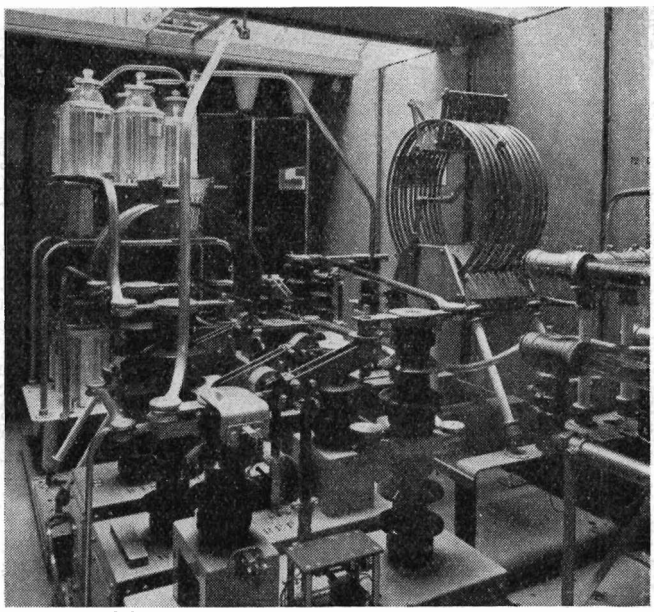
A certain amount of trouble has been experienced with the uniselectors mainly due to worn brass ratchet wheels and fatigued return springs, but considering the enormous number of operating cycles to which these are subjected, this is not surprising. In no cases have the fixed contacts developed any trouble, and all replacements have been carried out without the necessity for disconnecting any wires other than the four to the uniselector coil and self-run contact. From previous experience the layout has been designed so that, if necessary, the whole operating mechanism may be removed and serviced, while still leaving the contact banks wired in place.

In general these auto-checkers have proved of great use to a production unit and since they are adaptable to any set, their initial cost is soon repaid in test time saved.

Acknowledgments

Thanks are due to Mr. A. E. Harding for valuable advice and encouragement during the initial stages of the work, and to the Directors of Messrs. E. K. Cole, Ltd., for permission to publish this paper.

THE AERIAL COMBINING UNIT AT DAVENTRY



The first high-power transmitter to be operated by remote control is built as two identical units, mutually independent, the outputs of which are combined. Thus if either unit fails, the station can continue operating on reduced power using the remaining good unit.*

The combining circuits in which the outputs from the two halves of the transmitter are normally connected in parallel, are illustrated above. The circuit design also permits either half of the transmitter to be connected directly to the aerial feeder in the event of a breakdown of the other half. This changeover is automatically effected by electrically operated high-frequency contractors.

* Remote control of B.B.C. High-Power Transmitter. *Electronic Engg.* *24*, 229 (1952).

Matric Theory Applied to Thermionic Valve Circuits

By Sidney R. Deards *

THE method of dealing with the steady state analysis of passive quadripoles in terms of the matrix of the linear transformation expressed by the network equations was introduced by Strecker and Feldtkeller[1] in 1929 and has since been the subject of extensive treatment in the literature.[2] Despite the initiative taken by several writers, notably Brown and Bennett,[3] less consideration appears to have been given to the application of matric theory to networks containing thermionic valves. It is the intention in this article therefore to demonstrate how the matric theory of linear quadripoles is readily extended to include thermionic valves as constituent network elements.

The use of matric algebra in the study of network behaviour has yet to produce a stable notational system. The notation adopted herein has been devised in an effort to realize a system that is consistent and uniform.

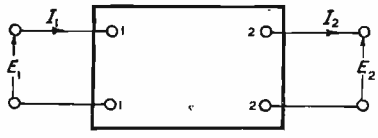


Fig. 1. General quadripole with reference directions for voltage and current

Assuming the reader to be familiar with the matric theory of passive quadripoles we may begin by recalling the six matric equations defining the network shown in Fig. 1. A capital Old English letter will be used to denote a transformation matrix and the corresponding capital Roman letter will be used to indicate the determinant of the matrix. The equations are:

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \end{bmatrix} = \mathfrak{Y} \begin{bmatrix} E_1 \\ E_2 \end{bmatrix} = \frac{\operatorname{adj} \mathfrak{Z}}{\mathrm{Z}} \begin{bmatrix} E_1 \\ E_2 \end{bmatrix} = \mathfrak{Z}^{-1} \begin{bmatrix} E_1 \\ E_2 \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} E_1 \\ E_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \mathfrak{Z} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \frac{\operatorname{adj} \mathfrak{Y}}{\mathrm{Y}} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \mathfrak{Y}^{-1} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} E_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ E_2 \end{bmatrix} = \mathfrak{H} \begin{bmatrix} I_1 \\ E_2 \end{bmatrix} = \frac{\operatorname{adj} \mathfrak{G}}{\mathrm{G}} \begin{bmatrix} I_1 \\ E_2 \end{bmatrix} = \mathfrak{G}^{-1} \begin{bmatrix} I_1 \\ E_2 \end{bmatrix} \quad (3)$$

$$\begin{bmatrix} I_1 \\ E_2 \end{bmatrix} = \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \begin{bmatrix} E_1 \\ I_2 \end{bmatrix} = \mathfrak{G} \begin{bmatrix} E_1 \\ I_2 \end{bmatrix} = \frac{\operatorname{adj} \mathfrak{H}}{\mathrm{H}} \begin{bmatrix} E_1 \\ I_2 \end{bmatrix} = \mathfrak{H}^{-1} \begin{bmatrix} E_1 \\ I_2 \end{bmatrix} \quad (4)$$

$$\begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} = \mathfrak{A} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} = \frac{\operatorname{adj} \mathfrak{B}}{\mathrm{B}} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} = \mathfrak{B}^{-1} \begin{bmatrix} E_2 \\ I_2 \end{bmatrix} \quad (5)$$

$$\begin{bmatrix} E_2 \\ I_2 \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \mathfrak{B} \begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \frac{\operatorname{adj} \mathfrak{A}}{\mathrm{A}} \begin{bmatrix} E_1 \\ I_1 \end{bmatrix} = \mathfrak{A}^{-1} \begin{bmatrix} E_1 \\ I_1 \end{bmatrix} \quad (6)$$

in which adj $\mathfrak{Z}$, for example, denotes the adjoint matrix of $\mathfrak{Z}$ with elements $\mathbf{Z}_{ji}$. The relations between the transformation matrix elements in (1) to (6) are tabulated in Appendix A from which we note that if the elements of $\mathfrak{A}$ are expressed in terms of the elements of $\mathfrak{Z}$ and $\mathfrak{Y}$ thus:

$$\mathfrak{A} = \begin{bmatrix} \frac{z_{11}}{z_{21}} & -\frac{\mathrm{Z}}{z_{21}} \\ \frac{1}{z_{21}} & -\frac{z_{22}}{z_{21}} \end{bmatrix} = \begin{bmatrix} -\frac{y_{22}}{y_{21}} & \frac{1}{y_{21}} \\ -\frac{\mathrm{Y}}{y_{21}} & \frac{y_{11}}{y_{21}} \end{bmatrix}$$

the determinant **A** may be written:

$$\mathbf{A} = -z_{12}/z_{21} = -y_{12}/y_{21} \quad \ldots\ldots\ldots \quad (7)$$

Since the principle of reciprocity is valid for a linear passive network, the mutual impedance (and, consequently, the transfer admittance) is bilateral. That is, according to the convention adopted in Fig. 1, $-z_{12} = z_{21}$ and $-y_{12} = y_{21}$. The value of unity for **A** therefore characterizes a passive network.

The Valve in Linear Operation

In Fig. 2 the arbitrary quadripole of Fig. 1 is replaced by a triode valve but the discussion that follows applies equally to multi-electrode valves provided the auxiliary electrode potentials are held constant in operation so that i_g and i_a are functions only of e_g and e_a according to the transformation:

$$i_g = y_{11}e_g + y_{12}e_a$$
$$-i_a = y_{21}e_g + y_{22}e_a$$

The significance of the coefficients y_{ij} is disclosed by differentiating each equation with respect to e_g and e_a in turn.

$$\delta i_g = (\partial i_g/\partial e_g)\,\delta e_g + (\partial i_g/\partial e_a)\,\delta e_a$$
$$\delta i_a = (\partial i_a/\partial e_g)\,\delta e_g + (\partial i_a/\partial e_a)\,\delta e_a \quad \ldots\ldots\ldots \quad (8)$$

If δi_a is restricted to the part of the characteristic curve for which the mutual conductance $\partial i_a/\partial e_g$ and the anode conductance $\partial i_a/\partial e_a$ remain approximately constant, the valve, although a non-linear element, may be regarded as a linear system. Furthermore, if the quiescent grid potential is maintained sufficiently negative, the grid conductance $\partial i_g/\partial e_g$ and reflex mutual conductance $\partial i_g/\partial e_a$ vanish and the grid is never in conduction (Class-A operation). In these circumstances Equations (8) may be written:

$$i_g = 0$$
$$i_a = g_m e_g + g_a e_a \quad \ldots\ldots\ldots\ldots \quad (9)$$

where $g_m = \partial i_a/\partial e_g$ and $g_a = 1/r_a = \partial i_a/\partial e_a$.

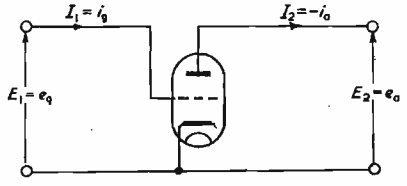


Fig. 2. The valve represented as a quadripole

If now we substitute from Fig. 2 the equalities:

$$i_g = I_1\ ;\ -i_a = I_2\ ;\ e_g = E_1\ ;\ e_a = E_2$$

in Equation (9) we obtain:

$$I_1 = 0$$
$$I_2 = -g_m E_1 - g_a E_2$$

* *The College of Aeronautics.*

from which we are able to write the admittance matrix of the valve in linear, Class-A operation.

$$\mathbb{Y} = \begin{bmatrix} \cdot & \cdot \\ -g_m & -g_a \end{bmatrix}$$

Because the grid current coefficients are zero the rank of $\mathbb{Y}$ is less than its order; the matrix is therefore singular and the inverse matrix $\mathbb{Z}$ defining the valve in Class-A operation does not exist. However, if a passive impedance element Z_g is placed in shunt with the valve input, as shown in Fig. 3(a), the admittance matrix of the network

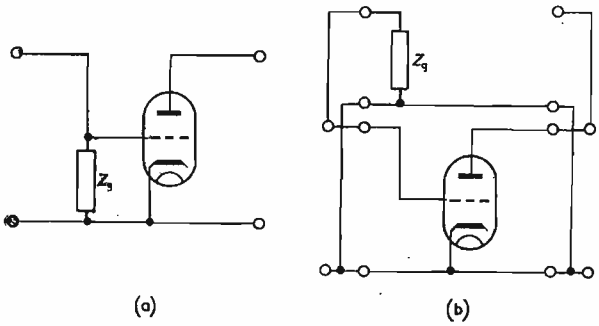


Fig. 3. Circuit for obtaining a non-singular admittance matrix

thus formed is non-singular.[3] Decomposing the combination according to the scheme shown in Fig. 3(b) it is evident that the required matrix is given by the sum of the admittance matrices of the upper and lower quadripoles. Writing Y_g for $1/Z_g$ we obtain:

$$\mathbb{Y} = \begin{bmatrix} Y_g & \cdot \\ \cdot & \cdot \end{bmatrix} + \begin{bmatrix} \cdot & \cdot \\ -g_m & -g_a \end{bmatrix} = \begin{bmatrix} Y_g & \cdot \\ -g_m & -g_a \end{bmatrix} \quad (10)$$

whence, employing the relations in Appendix A,

$$\mathbb{Z} = \begin{bmatrix} Z_g & \cdot \\ -\mu Z_g & -r_a \end{bmatrix} \quad (11)$$

where $\mu = g_m/g_a$ and $r_a = 1/g_a$. It is to be noticed that, unlike the corresponding matrix coefficients of passive structures, $-y_{12} \neq y_{21}$ and $-z_{12} \neq z_{21}$. Active structures are therefore, in general, distinct from passive structures in that the principle of reciprocity is not valid. In particular, (10) and (11) have $y_{12} = z_{12} = 0$, indicating that the transfer of energy proceeds in only one direction. From (7) we conclude that $\mathfrak{A}$, corresponding to the quadripole of Fig. 3, is singular, therefore $\mathfrak{B}$ does not exist. A singular $\mathfrak{A}$ thus characterizes a pure unilateral network. It is pointed out, however, that no consideration has been given to the capacitances which, in reality, exist between the valve electrodes. The matrix (10) contains only conduction current coefficients. To these must be added the

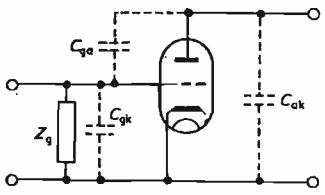


Fig. 4. Triode and its interelectrode capacitances

coefficients of the displacement currents due to the interelectrode capacitances if the admittance matrix is required in which the latter are represented. Ignoring the dielectric losses associated with these capacitances the admittance matrix for the circuit of Fig. 4 is easily shown to be:

$$\mathbb{Y} = \begin{bmatrix} Y_g + B_{gk} + B_{go} & -B_{go} \\ B_{go} - g_m & -(g_a + B_{ak} + B_{go}) \end{bmatrix}$$

where, for convenience, we write B for $j\omega C$.

It is to be observed that y_{12} is no longer zero therefore the network of Fig. 4 is not purely unilateral; reverse transduction is possible by way of the grid-anode susceptance.

The matrix (10) or (11) may be transformed to any other matrix by employing the equalities in Appendix A. This has been done and the results listed in Appendix B.

Modification of Coefficients by Cathode Impedance

When a passive impedance Z_k is introduced in series with the cathode, as shown in Fig. 5, the anode current

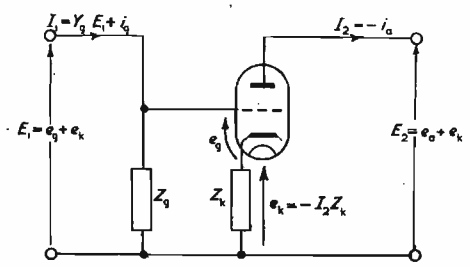


Fig. 5. Triode with impedance in the cathode circuit

coefficients are modified. From Fig. 5 we have:

$i_g = I_1 - Y_g E_1$; $-i_a = I_2$; $e_g = E_1 + I_2 Z_k$; $e_a = E_2 + I_2 Z_k$

which, when substituted in (9), yield:

$$I = Y_g E_1$$
$$I_2 = -g_m(E_1 + I_2 Z_k) - g_a(E_2 + I_2 Z_k)$$

giving, after collecting terms,

$$\mathbb{Y} = \begin{bmatrix} Y_g & \cdot \\ -\dfrac{g_m}{1 + Z_k(g_m + g_a)} & -\dfrac{g_a}{1 + Z_k(g_m + g_a)} \end{bmatrix}$$

from which the related matrices may be obtained. These appear in Appendix B. On comparing $\mathfrak{G}$ for the circuit of Fig. 5 with the corresponding matrix for the circuit of Fig. 3, we conclude that a triode with an impedance Z_k in series with its cathode is equivalent to a simple triode having the same μ but an apparent anode resistance of $r_a + Z_k(1 + \mu)$.

Cathode-Follower

If the anode is at earth potential instead of the cathode, as in Fig. 6, the system becomes a cathode-follower. According to Fig. 6

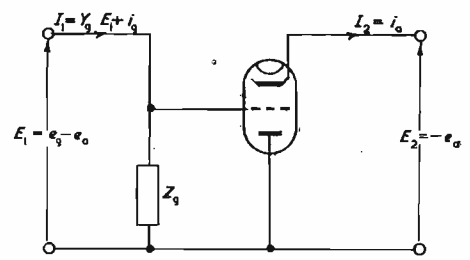
$I_g = I_1 - Y_g E_1$; $i_a = I_2$; $e_g = E_1 - E_2$; $e_a = -E_2$

Substituting these equalities in (9) we obtain the admittance matrix for the cathode-follower connexion.

$$\mathbb{Y} = \begin{bmatrix} Y_g & \cdot \\ g_m & -(g_m + g_a) \end{bmatrix}$$

The related matrices are listed in Appendix B.

Fig. 6. Earthed anode connexion



Inverted Amplifier

The earthed grid or inverted amplifier is obtained when the grid is operated at earth potential as shown in Fig. 7.

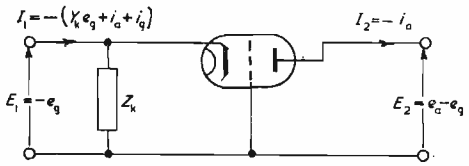


Fig. 7. Earthed grid connexion

Substituting in (9) the equalities

$$i_g = Y_k E_1 + I_2 - I_1 \; ; \; -i_a = I_2 \; ; \; -e_g = E_1 \; ; \; e_a = E_2 - E_1$$

yields

$$\mathbb{Y} = \begin{bmatrix} Y_k + g_m + g_a & -g_a \\ g_m + g_a & -g_a \end{bmatrix}$$

from which the associated matrices tabulated in Appendix B may be derived. It is to be noted that $\mathbf{A} = -y_{12}/y_{21} = 1/(1 + \mu)$ for the valve in this connexion; consequently $\mathfrak{B}$ exists. This indicates that the earthed grid connexion differs from the earthed cathode and earthed anode connexions in that it does not produce a pure unilateral system. The admittance matrix shows that reverse transduction occurs via the anode conductance.

Gain and Terminal Admittances of a Cathode-Follower

As an example in the application of the foregoing results to the solution of thermionic valve circuits it is proposed to analyse the cathode-follower circuit shown in Fig. 8(a). Z_k is the cathode load, R_g the grid resistor and C_{ga}, C_{gk}, C_{ak} and C_{hk} are the capacitances between the electrodes indicated by the suffices. We shall assume that the bias resistor R_b is effectively decoupled by the capacitor C_b. We make the further assumption that the anode supply is adequately decoupled and therefore plays

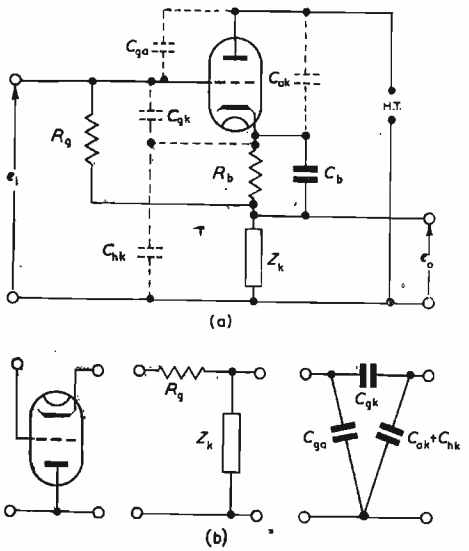


Fig. 8. Cathode-follower and its decomposition into constituent paralleled quadripoles

no part in the analysis. For our purpose the circuit may be regarded as the parallel composition of the networks shown in Fig. 8(b). Summing the admittance matrices corresponding to these networks we obtain the admittance matrix of the circuit in Fig. 8(a).

$$\mathbb{Y} = \begin{bmatrix} \cdot & \cdot \\ g_m & -(g_m + g_g) \end{bmatrix} + \begin{bmatrix} G_g & -G_g \\ G_g & -(G_g + Y_k) \end{bmatrix} + \begin{bmatrix} B_{ga} + B_{gk} & -B_{gk} \\ B_{gk} & -(B_{ak} + B_{hk} + B_{gk}) \end{bmatrix}$$

$$= \begin{bmatrix} G_g + B_{ga} + B_{gk} & -(G_g + B_{gk}) \\ g_m + G_g + B_{gk} & -(g_m + g_a + G_g + Y_k + B_{ak} + B_{hk} + B_{gk}) \end{bmatrix}$$

The voltage gain M of the cathode-follower is given by the ratio of the forward transfer admittance (y_{21}) to the short circuit output admittance ($-y_{22}$). We may write at once therefore

$$M = \frac{g_m + G_g + B_{gk}}{g_m + g_a + G_g + Y_k + B_{ak} + B_{hk} + B_{gk}}$$

or

$$\frac{(r_a G_g + \mu + j\omega C_{gk} r_a) Z_k}{r_a(Z_k G_g + 1) + Z_k(1 + \mu) + j\omega(C_{ak} + C_{hk} + C_{gk}) r_a Z_k}$$

which, if the interelectrode capacitances may be ignored and the conductance of R_g is negligibly small, reduces to the familiar expression

$$M = \frac{\mu Z_k}{r_a + Z_k(1 + \mu)}$$

The input admittance is given by the reciprocal of the coefficient z_{11}. From Appendix A we have $1/z_{11} = \mathbf{Y}/y_{22}$, accordingly

$$Y_i = B_{ga} + (G_g + B_{gk}) - \frac{(G_g + B_{gk})(g_m + G_g + B_{gk})}{g_m + g_a + G_g + Y_k + B_{ak} + B_{hk} + B_{gk}}$$

$$= G_g(1 - M) + B_{ga} + B_{gk}(1 - M)$$

$$= G_g(1 - M) + j\omega [C_{ga} + C_{gk}(1 - M)]$$

If M is real and, as is usually the case, approximately 0.9. the input admittance has a real component due to the grid resistor R_g, the value of which appears to be approximately $10 R_g$, and an imaginary component due to an effective capacitance of approximately $C_{ga} + 0.1 C_{gk}$ signifying a tenfold increase in the grid-cathode reactance. In these circumstances the input admittance of the valve alone is a pure susceptance.

The output admittance is simply $-y_{22}$. We have therefore

$$Y_o = g_m + g_a + G_g + Y_k + B_{ak} + B_{hk} + B_{gk}$$

$$= g_m + g_a + G_g + Y_k + j\omega(C_{ak} + C_{hk} + C_{gk})$$

which, over the frequency range of e_i for which the susceptance term is negligible, becomes

$$Y_o = g_m + g_a + G_g + Y_k \approx g_m$$

Conclusion

The matric theory of four-terminal networks is thus shown to include the thermionic valve in linear operation with the distinction that the value of the determinant **A** is less than unity. The matrices of the valve may be combined with those of passive networks, according to the rules of matric algebra, for the purpose of developing the matrices of composite quadripoles. The organization and discipline inherent in the notation of matric algebra provide an attractive method of thermionic valve circuit analysis which should appeal to the engineer.

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(Appendices on following page)

APPENDIX A

Relations between the matrix elements

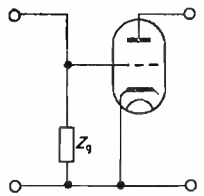
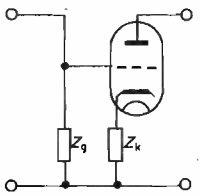
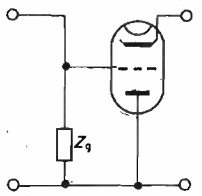
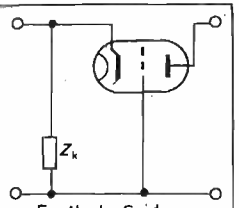
a_{11}		$b_{22}/\mathbf{B}$	$-y_{22}/y_{21}$	z_{11}/z_{21}	$-\mathbf{H}/h_{21}$	$1/g_{21}$
a_{12}		$-b_{12}/\mathbf{B}$	$1/y_{21}$	$-\mathbf{Z}/z_{21}$	h_{11}/h_{21}	$-g_{22}/g_{21}$
a_{21}		$-b_{21}/\mathbf{B}$	$-\mathbf{Y}/y_{21}$	$1/z_{21}$	$-h_{22}/h_{21}$	g_{11}/g_{21}
a_{22}		$b_{11}/\mathbf{B}$	y_{11}/y_{21}	$-z_{22}/z_{21}$	$1/h_{21}$	$-\mathbf{G}/g_{21}$
b_{11}	$a_{22}/\mathbf{A}$		$-y_{11}/y_{12}$	z_{22}/z_{12}	$1/h_{12}$	$-\mathbf{G}/g_{12}$
b_{12}	$-a_{12}/\mathbf{A}$		$1/y_{12}$	$-\mathbf{Z}/z_{12}$	$-h_{11}/h_{12}$	g_{22}/g_{12}
b_{21}	$-a_{21}/\mathbf{A}$		$-\mathbf{Y}/y_{12}$	$1/z_{12}$	h_{22}/h_{12}	$-g_{11}/g_{12}$
b_{22}	$a_{11}/\mathbf{A}$		y_{22}/y_{12}	$-z_{11}/z_{12}$	$-\mathbf{H}/h_{12}$	$1/g_{12}$
y_{11}	a_{22}/a_{12}	$-b_{11}/b_{12}$		$z_{22}/\mathbf{Z}$	$1/h_{11}$	$\mathbf{G}/g_{22}$
y_{12}	$-\mathbf{A}/a_{12}$	$1/b_{12}$		$-z_{12}/\mathbf{Z}$	$-h_{12}/h_{11}$	g_{12}/g_{22}
y_{21}	$1/a_{12}$	$-\mathbf{B}/b_{12}$		$-z_{21}/\mathbf{Z}$	h_{21}/h_{11}	$-g_{21}/g_{22}$
y_{22}	$-a_{11}/a_{12}$	b_{22}/b_{12}		$z_{11}/\mathbf{Z}$	$\mathbf{H}/h_{11}$	$1/g_{22}$
z_{11}	a_{11}/a_{21}	$-b_{22}/b_{21}$	$y_{22}/\mathbf{Y}$		$\mathbf{H}/h_{22}$	$1/g_{11}$
z_{12}	$-\mathbf{A}/a_{21}$	$1/b_{21}$	$-y_{12}/\mathbf{Y}$		h_{12}/h_{22}	$-g_{12}/g_{11}$
z_{21}	$1/a_{21}$	$-\mathbf{B}/b_{21}$	$-y_{21}/\mathbf{Y}$		$-h_{21}/h_{22}$	g_{21}/g_{11}
z_{22}	$-a_{22}/a_{21}$	b_{11}/b_{21}	$y_{11}/\mathbf{Y}$		$1/h_{22}$	$\mathbf{G}/g_{11}$
h_{11}	a_{12}/a_{22}	$-b_{12}/b_{11}$	$1/y_{11}$	$\mathbf{Z}/z_{22}$		$g_{22}/\mathbf{G}$
h_{12}	$\mathbf{A}/a_{22}$	$1/b_{11}$	$-y_{12}/y_{11}$	z_{12}/z_{22}		$-g_{12}/\mathbf{G}$
h_{21}	$1/a_{22}$	$\mathbf{B}/b_{11}$	y_{21}/y_{11}	$-z_{21}/z_{22}$		$-g_{21}/\mathbf{G}$
h_{22}	$-a_{21}/a_{22}$	b_{21}/b_{11}	$\mathbf{Y}/y_{11}$	$1/z_{22}$		$g_{11}/\mathbf{G}$
g_{11}	a_{21}/a_{11}	$-b_{21}/b_{22}$	$\mathbf{Y}/y_{22}$	$1/z_{11}$	$h_{22}/\mathbf{H}$	
g_{12}	$\mathbf{A}/a_{11}$	$1/b_{22}$	y_{12}/y_{22}	$-z_{12}/z_{11}$	$-h_{12}/\mathbf{H}$	
g_{21}	$1/a_{11}$	$\mathbf{B}/b_{22}$	$-y_{21}/y_{22}$	z_{21}/z_{11}	$-h_{21}/\mathbf{H}$	
g_{22}	$-a_{12}/a_{11}$	b_{12}/b_{22}	$1/y_{22}$	$\mathbf{Z}/z_{11}$	$h_{11}/\mathbf{H}$	

Determinants

$\mathbf{A}$	$a_{11}\ a_{22}-a_{12}\ a_{21}$	$\mathbf{B}^{-1}$	$-y_{12}/y_{21}$	$-z_{12}/z_{21}$	h_{12}/h_{21}	g_{12}/g_{21}
$\mathbf{B}$	$b_{11}\ b_{22}-b_{12}\ b_{21}$	$\mathbf{A}^{-1}$	$-y_{21}/y_{12}$	$-z_{21}/z_{12}$	h_{21}/h_{12}	g_{21}/g_{12}
$\mathbf{Y}$	$y_{11}\ y_{22}-y_{12}\ y_{21}$	$\mathbf{Z}^{-1}$	h_{22}/h_{11}	g_{11}/g_{22}	$-b_{21}/b_{12}$	$-a_{21}/a_{12}$
$\mathbf{Z}$	$z_{11}\ z_{22}-z_{12}\ z_{21}$	$\mathbf{Y}^{-1}$	h_{11}/h_{22}	g_{22}/g_{11}	$-b_{12}/b_{21}$	$-a_{12}/a_{21}$
$\mathbf{H}$	$h_{11}\ h_{22}-h_{12}\ h_{21}$	$\mathbf{G}^{-1}$	y_{22}/y_{11}	z_{11}/z_{22}	$-b_{22}/b_{11}$	$-a_{11}/a_{22}$
$\mathbf{G}$	$g_{11}\ g_{22}-g_{12}\ g_{21}$	$\mathbf{H}^{-1}$	y_{11}/y_{22}	z_{22}/z_{11}	$-b_{11}/b_{22}$	$-a_{22}/a_{11}$

APPENNDIX B

The matrices of the valve

	Earthed Cathode	Cathode Feedback	Earthed Anode	Earthed Grid
				
$\mathbf{A}$	$\begin{bmatrix} -\frac{1}{\mu} & -\frac{1}{g_m} \\ -\frac{1}{\mu Z_g} & -\frac{1}{g_m Z_g} \end{bmatrix}$	$\begin{bmatrix} -\frac{1}{\mu} & -\frac{1+Z_k(g_m+g_a)}{g_m} \\ -\frac{1}{\mu Z_g} & -\frac{1+Z_k(g_m+g_a)}{g_m Z_g} \end{bmatrix}$	$\begin{bmatrix} \frac{1+\mu}{\mu} & \frac{1}{g_m} \\ \frac{1+\mu}{\mu Z_g} & \frac{1}{g_m Z_g} \end{bmatrix}$	$\begin{bmatrix} \frac{1}{1+\mu} & \frac{r_a}{1+\mu} \\ \frac{1}{Z_k(1+\mu)} & \frac{r_a+Z_k(1+\mu)}{Z_k(1+\mu)} \end{bmatrix}$
$\mathbf{B}$	Does not exist	Does not exist	Does not exist	$\begin{bmatrix} r_a Y_k+\mu+1 & -r_a \\ -Y_k & 1 \end{bmatrix}$
$\mathbb{Y}$	$\begin{bmatrix} Y_g & \cdot \\ -g_m & -g_a \end{bmatrix}$	$\begin{bmatrix} Y_g & \cdot \\ -\frac{g_m}{1+Z_k(g_m+g_a)} & -\frac{g_a}{1+Z_k(g_m+g_a)} \end{bmatrix}$	$\begin{bmatrix} Y_g & \cdot \\ g_m & -(g_m+g_a) \end{bmatrix}$	$\begin{bmatrix} Y_k+g_m+g_a & -g_a \\ g_m+g_a & -g_a \end{bmatrix}$
$\mathbb{Z}$	$\begin{bmatrix} Z_g & \cdot \\ -\mu Z_g & -r_a \end{bmatrix}$	$\begin{bmatrix} Z_g & \cdot \\ -\mu Z_g & -[r_a+Z_k(1+\mu)] \end{bmatrix}$	$\begin{bmatrix} Z_g & \cdot \\ \frac{\mu Z_g}{1+\mu} & -\frac{r_a}{1+\mu} \end{bmatrix}$	$\begin{bmatrix} Z_k & -Z_k \\ Z_k(1+\mu) & -[r_a+Z_k(1+\mu)] \end{bmatrix}$
$\mathbb{D}$	$\begin{bmatrix} Z_g & \cdot \\ -g_m Z_g & -g_a \end{bmatrix}$	$\begin{bmatrix} Z_g & \cdot \\ \frac{g_m Z_g}{1+Z_k(g_m+g_a)} & -\frac{g_a}{1+Z_k(g_m+g_a)} \end{bmatrix}$	$\begin{bmatrix} Z_g & \cdot \\ g_m Z_g & -(g_m+g_a) \end{bmatrix}$	$\begin{bmatrix} \frac{r_a Z_k}{r_a+Z_k(1+\mu)} & \frac{Z_k}{r_a+Z_k(1+\mu)} \\ \frac{Z_k(1+\mu)}{r_a+Z_k(1+\mu)} & \frac{1}{r_a+Z_k(1+\mu)} \end{bmatrix}$
$\mathbb{G}$	$\begin{bmatrix} Y_g & \cdot \\ -\mu & -r_a \end{bmatrix}$	$\begin{bmatrix} Y_g & \cdot \\ -\mu & -[r_a+Z_k(1+\mu)] \end{bmatrix}$	$\begin{bmatrix} Y_g & \cdot \\ \frac{\mu}{1+\mu} & -\frac{r_a}{1+\mu} \end{bmatrix}$	$\begin{bmatrix} Y_k & 1 \\ 1+\mu & -r_a \end{bmatrix}$

Some Problems in
Audio Frequency Spectrum Analysis

(Part 1)

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

Many of the problems of spectrum analysis become increasingly difficult at low frequencies where the time of one cycle becomes comparable with the total time available for the analysis. Part 1 of this article describes some of the theoretical consideration involved; Part 2 will describe some of the features of an experimental analyser that has been built to verify the theoretical predictions.

A SPECTRUM analyser basically requires only a selective circuit which can be tuned to all frequencies in the range being studied. An equivalent procedure is to use a fixed selective circuit and pass through it one of the heterodyne tones between the signal being observed and a variable frequency local oscillator. Consequently, for each frequency of this oscillator, there exists a corresponding input frequency which will produce the desired combination frequency. If then the local oscillator frequency is changed continuously, so will the input frequency to the filter. The output to be measured will then be the response of a selective circuit to a varying frequency, and can be displayed on a cathode-ray tube, whose horizontal deflexion voltage is synchronized with the local oscillator sweep signal. As the rate of sweeping is increased, the transients of the filter make the response appreciably different from that obtained with slow rates of sweeping, imposing a severe physical limitation on the maximum speed with which an analysis may be made. An approximate statement of the necessary condition is: "The rate of sweeping must not exceed the square of the bandwidth."

Response of a Tuned Circuit to a Signal of Varying Frequency

The "instantaneous" frequency applied to the filter may be expressed as

$$f_i = f_o + at$$

where a is the rate of sweeping which is assumed constant. The resonant frequency of the filter will be denoted by f_r, and in the usual way we may define

$$Q = f_r/\Delta f.$$

Various authors[1,2,3] have treated this problem qualitatively by different methods. Typical of these is Walter,[2] who states that the time in the pass-band of the filter is approximately $\Delta f/a$, which must be at least equal to the time-constant of the filter which he takes as $1/\Delta f$. Then

$$\Delta f/a \geqslant 1/\Delta f$$

or $a \leqslant \Delta f^2$ as stated above.

The other authors arrive at similar results using similar arguments. The stated upper limits for the value of $a/\Delta f^2$ range from 0·24 to 6·4. As no quantitative limit on the tolerable change in output is given, all these results should be considered as agreeing in magnitude.

The earliest quantitative solution to this problem was given by Lewis[4] in 1932. He dealt with the analogous mechanical problem of vibration during acceleration of rotating machinery through a critical speed, and solved the differential equation by operational methods. The solution involves Fresnel integals of complex argument which are not known to be tabulated to any extent even now. Lewis reduced these integrals to a form from which he could evaluate them by a geometrical construction. He plots a separate set of curves for each value of Q, and generally only a small part of the curve near resonance. The most interesting feature of these curves is evident when the rate of sweeping or the Q is large. The amplitude of the vibration after the resonant point is reached does not decay monotonically, but shows relatively low frequency oscillations, which are beats between the applied frequency and the transient "ringing" set up in the resonant circuit. In general, the result of increasing the ratio $a/\Delta f^2$ is twofold: there is a decrease in the peak amplitude, and there is a distortion in the shape of the resonance curve. He also shows that for a decreasing frequency, the amplitudes are slightly greater than for an increasing frequency—1 or 2 per cent for $a \approx \Delta f^2$. This will be true only if the Q is low, where the response of the resonant circuit at $2f_r$ is not negligible. In most electronic problems, and certainly in the cases of interest in a spectrum analyser, the Q is necessarily large to give good resolution, the response curve is symmetrical, and there is no difference due to the direction of sweeping.

The general theoretical problem of the response of a tuned circuit to a varying frequency has been also considered by Barber and Ursell,[5] Hamilton,[6] and Hok.[7] Their methods of solution are quite different but their results are essentially the same. Some of the more practical considerations have been dealt with by Thomasson,[1,8] and Barber.[9]

Most of the papers mentioned above do not in themselves indicate the conditions under which the limitations become of importance. Let us assume we wish to analyse a band of frequencies F cycles wide. For a bandwidth Δf, we can resolve $n = F/\Delta f$ equally spaced components. The time T required to analyse this band once is given by:

$$T = F/a = F/\Delta f^2 = n^2/F.$$

Thus for a given resolution, the time per sweep becomes very long when a large number of components must be resolved in a small frequency interval.

It is important to note that the change in amplitude is of but little consequence when sweeping at a constant rate with a fixed bandwidth. This is the most satisfactory way of making a harmonic analysis as the different frequency components are spread out uniformly on the output graph. The percentage change in amplitude will then be the same for all components and their relative amplitudes will remain correct. With a logarithmic frequency sweep this will not be so, unless the bandwidth is varied so that the value of $a/\Delta f^2$ remains constant or is sufficiently small at all times.

Two aspects of the general problem are not discussed in any of the published papers. The first is the behaviour if the initial conditions are not zero (e.g. current flowing through L and/or charge on C, in the case of an LC filter). It can be shown easily, however, that this will produce a

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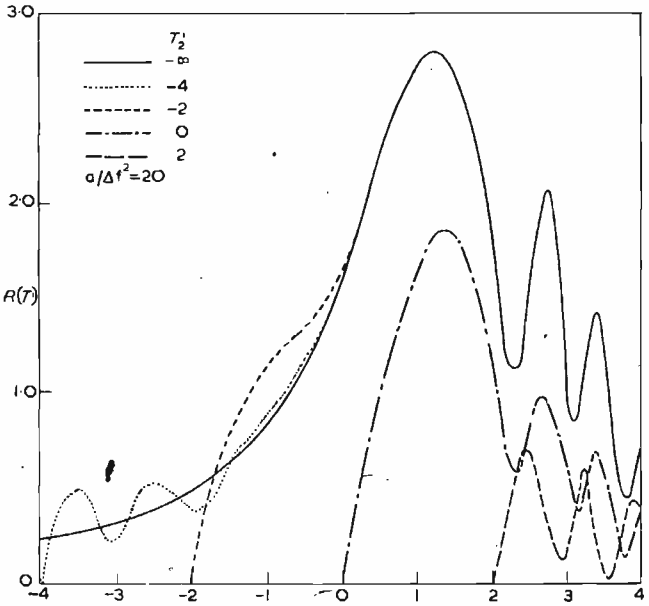


Fig. 1. Response of a Resonant Circuit to an Applied Signal Varying Linearly with Frequency

transient current of the form

$$e^{-mt} \sin \omega t,$$

which is the complementary function of the differential equation. With a cathode-ray type of display as described above, this effect is observable with a repetitive sweep if the signal level is not zero at the end of the previous sweep. The next trace then starts at an amplitude which is the same as that at the end of the previous sweep, and this decays to zero exponentially.

The other problem is a determination of the effects of starting the sweep in or near the pass-band. This is of great importance in variable-limit spectrum analysers. The solution of this latter problem is most easily obtained by an extension of the work of Barber and Ursell.[5] The mathematical details will be omitted here as they can be found in the original paper. These workers consider the response of a mechanical system (a galvanometer) to an applied force:

$$E(t) = E_0 \sin (b + \omega t + \pi a t^2)$$

where a is the same parameter as used above. The differential equation of motion is of the form:

$$d^2x/dt^2 + 2n\omega\, dx/dt + \omega^2 x = \frac{E(t)}{M}$$

With no applied force, the free motion of such a system is a damped oscillation. With a given applied force $E(t)$, the motion can be found by replacing $E(t)$ by a series of impulses $E(T)\,dT$. The free motions of the system following each of these impulses may be added together to give the total deflexion at some later time t. If the initial applied frequency is far enough removed from the resonant frequency of the system that its response is negligible, then the integral may be taken from $-\infty$ to t without loss of accuracy. In general, however, the applied force will start at f_1 corresponding to t_1, and this may be near the resonant frequency. The integral must then be taken from t_1 to t. Mathematically this is expressed as:

$$x(t) = \int_{t_1}^{t} F(t,T)\,dT = \int_{-\infty}^{t} F(t,T)\,dT - \int_{-\infty}^{t_1} F(t,T)\,dT$$

The paper of Barber and Ursell provides the means of evaluating the last two integrals, and so the complete solution can be obtained. A graph of the response $R(T')$ for different values of T'_1 is shown in Fig. 1. T' is a generalized time and is directly proportional to true time (or frequency) according to the relation $T' = t\sqrt{\pi a}$. The value of a $a/\Delta f^2$ has been chosen rather high to exaggerate the condition somewhat. It will be noted that the peak amplitude is reduced unless the sweep is started at such a frequency that most of the pass-band is covered. The "oscillations" near the beginning of the sweep have been observed experimentally, and were the object of considerable interest and speculation before the theory was worked out.

Selective Circuit Used

The analyser which has been built is essentially a panoramic superheterodyne receiver with a 50kc/s I.F. Double conversion is employed to increase the maximum selectivity by using an additional 1kc/s amplifier stage. Some of the reasons for the choice of these frequencies will be discussed in Part 2. The parallel-T inverse feedback amplifier was chosen for these circuits to avoid the use of bulky inductances. The parallel-T network is shown between the points A and B in the circuit diagram, Fig. 2. It is characterized by a minimum transmission at a particular frequency and by suitable choice of component values this minimum can be made zero. Generally speaking, R_1 controls the "resonant" frequency and R_3 determines the minimum response of the network, although there is some interaction between the two. The analysis of the network has been given many times and so will not be repeated here. The reader is referred especially to Stanton,[10] Hastings,[11] and Hillan[12] for the mathematical details.

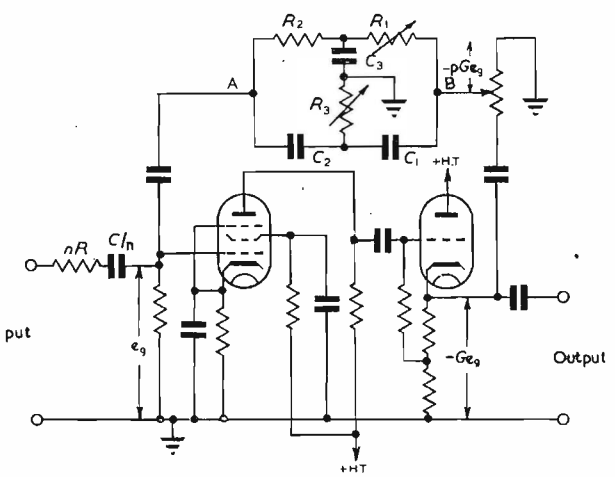
Now consider an amplifier with a normally flat frequency response characteristic and with a parallel-T null network connected between the plate and grid circuits, providing a path for degenerative feedback. At the null frequency f_0 of the network, there is no transmission through the network, and the amplifier operates at its full normal gain G. At any other frequency, the amplifier will be highly degenerative and its gain will accordingly be reduced to A, where

$$A = \frac{G}{1 - GT}$$

T being the network transmission. The effective Q of such a circuit is approximately $G/4$ for a symmetrical network ($\alpha = 0{\cdot}5$).[11] The detailed analysis of the circuit of Fig. 2 shows that this circuit is exactly equivalent to a simple series LCR circuit in that the value of the ratio of output voltage to input voltage can be expressed in the form

$$\frac{1}{R' + j\,(\omega L' - 1/\omega C')}$$

Fig. 2. Circuit of Selective Amplifier



where $R' = (2n/\alpha^2 + 1)G$,

$L' = n(1 + pG)/G\omega_o$,

$C' = G/n(1 + pG)\omega_o$,

and n is an arbitrary circuit parameter,

α is a measure of the symmetry of the network,

p is the fraction of the amplifier output voltage fed back to the input,

$\omega_o = 2\pi f_o$.

Therefore it follows that any signal applied to the bridge amplifier will produce exactly the same relative output as would be obtained if the same signal were applied to the equivalent series resonant circuit (including identical phase shifts at the same frequency). This is more clearly evident if we consider the applied signal to be expressed as a Fourier series (or in certain cases as a Fourier integral) in which case each component frequency can be considered individually. Since the network is strictly linear, the components can be added directly.

The resonant frequency of the bridge amplifier should be given by:

$$f_r = 1/2\pi\sqrt{L'C'}$$

and this equals f_o, which is the "null" frequency of the network alone. This would be expected because there is no feedback at that frequency, and therefore the amplifier has maximum gain.

$$Q = \omega_o L'/R' = \frac{\alpha^2 n(1 + pG)}{2n + \alpha^2}$$

In the final selective amplifier which has been built (the 1kc/s amplifier mentioned before), the approximate values of the parameters are $\alpha = 0{\cdot}9$, $n = 5$, $G = 250$, $p = 1$ (maximum). Therefore $Q = 100$ and since $f_o = 100$c/s, $\Delta f = 10$c/s. This is observed to be so.

Part 2 will describe some of the more interesting circuit details of the experimental model and will indicate some of the results of its operation.

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(To be continued)

Some New Multivibrators

By Lt.-Col. Chang Sing,* B.Sc., and Capt. Chu Yao-I,* B.Sc.

MANY types of multivibrator have been used, especially in connexion with radar, to produce fairly square waves of a specified or adjustable duration. In this article some new-free running multivibrators are introduced and these are interesting in that they have a peculiar arrangement of their circuit elements.

The first of these circuits is shown in Fig. 1. This may be considered to be a modified Eccles-Jordan trigger circuit with a capacitor inserted between cathode and earth on each of the two valves; to complete their D.C. path two resistors are added across the grids and cathodes. Although both grids are connected to H.T. the free-running condition can still be obtained by means of the charge and discharge of the cathode capacitors. When H.T. is applied, both grids are at a positive potential, both the valves draw heavy currents and the capacitors C_1 and C_2 start to charge exponentially. As C_1 and C_2 become charged the respective anode currents will decrease but, as a perfect balance of the circuit is impossible to attain there will be a slight difference in the rate of decrease of the two currents. Suppose V_2 anode current decreases more rapidly than V_1, this, in turn, causes V_2 anode potential to rise more quickly. In other words, the grid of V_2 is now at a lower potential than that of V_1 and, therefore V_2 reaches its grid cut-off region more quickly by means of the charge on C_2, at which time V_2 current further decreases. At a certain time the rise in potential of V_2 anode will cause V_1 grid to overcome the rate of charging of C_1, when V_1 anode current increases again. V_1 anode potential then drops and brings V_2 grid potential with it. This action causes V_2 anode potential to rise and makes V_1 conduct more. By the cumulative action V_1 conducts heavily and the drop in its anode partial is sufficient to bias V_2 grid beyond cut-off. C_1 charges up and tends to equalize the grid and cathode potentials of V_1. V_1 anode potential rises and brings V_2 grid potential with it. At the same time C_2 discharges through R_2 causing a reduction in V_2 cathode potential. As the potential of V_2 grid rises and the cathode decreases, the conducting point of V_2 will be reached and by cumulative action V_1 cuts off and V_2 conducts; C_2 charges to equalize the grid and cathode potentials of V_2, V_2 anode and V_1 grid potential rise and C_1 discharges through R_1 to make V_1 cathode potential decrease. V_1 then begins to draw current and the circuit is switched over and the action is then repeated in a similar manner. The waveforms of the potentials on the

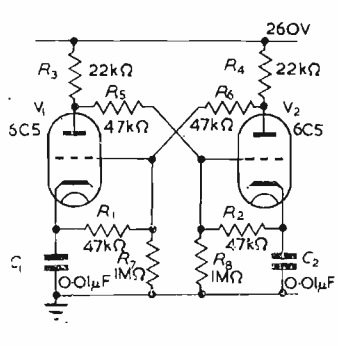


Fig. 1. Modified Eccles-Jordan circuit

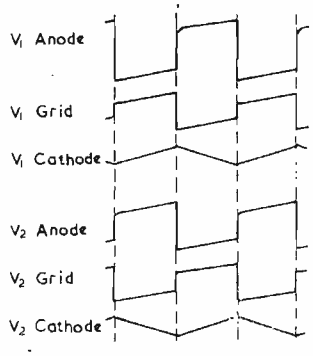


Fig. 2. Anode, grid and cathode waveforms of Fig. 1

* *Chinese Air Force.*

anodes, grids and cathodes of the two valves are shown in Fig. 2. There are two factors that will effect the square waveforms at the anodes, they are:—

(1) During the valve conduction, the bottom side of the waveform is sloping upwards due to the charging of its cathode capacitor.

(2) When the valve is cut-off, the anode potential cannot reach the full H.T. instantaneously due to the charge of the other capacitor.

The following points should be noted:—

(a) The switching action will still be provided when large values of capacitors C_1 and C_2 are used, satisfactory operation being obtained up to 10μF. It is also interesting to note what happens when small values of capacitors are used (e.g., 0.002μF). Since the small value capacitor is charged up to the grid potential so quickly the amount of the anode drop is not sufficient to bias the grid of the other valve beyond cut-off and the circuit becomes an ordinary positive feedback oscillator. The anode waveforms will then be sinusoidal.

(b) Any of the resistors in the dividing chain (R_3, R_5, R_8, R_4, R_6, R_7) may be used as a fine control for the repetition frequency. By using a large value for R_1 (or R_2) the discharging time will be lengthened while the repetition frequency will also be reduced. Course control is provided by using different values of capacitor.

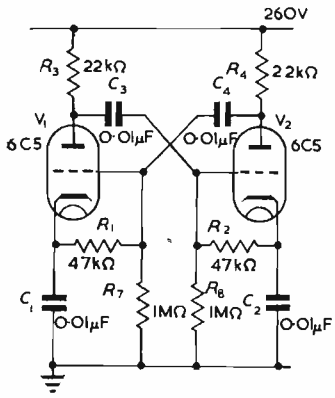


Fig. 3. Modified anode coupled multivibrator

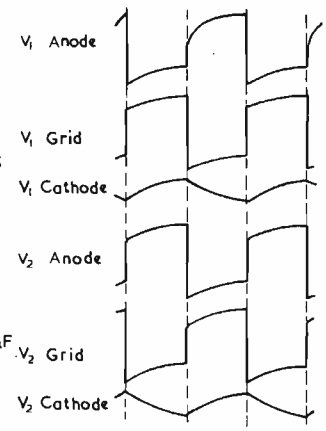


Fig. 4. Anode grid and cathode waveform of Fig. 3

(c) So far the action has been considered as symmetrical, i.e., with each corresponding pair of components matched in volume. The circuit will, however, function well as an assymmetric one.

(d) The circuit is effective from frequencies of a few cycles per second up to about 100kc/s.

A second new circuit is shown in Fig. 3. In this case two capacitors, C_3 and C_4, are used in place of the resistors R_5 and R_6. It may be considered as a modification of an anode-coupled multivibrator, the operation is, however, somewhat modified by capacitors C_1 and C_2 and resistors R_1 and R_2. It will be seen that the duration of the period between one change-over and the next is determined by:—

(1) The rate of decrease of potential on the cathode of the valve which has zero anode current at the time.

(2) The rate of rise of potential at the grid of the same valve.

Therefore the repetition frequency is controlled by C_1R_1 (or C_2R_2) in addition to the two coupling time-constants. The waveforms obtained are shown in Fig. 4. The anode and grid waveforms are similar to those produced from an anode coupled multivibrator except that the bottom of the anode waveform and the top of the grid waveform rise exponentially due to the charge of the cathode capacitor. The circuit works equally well as an assymmetric one. An important point to note is that if C_1 and C_2 are made large, say 0·1μF, instead of 0.01μF, the circuit becomes a blocking ringing multivibrator. Since the time-constant of the cathode circuit is large compared with that of the coupling circuit, the counting action takes place at each cathode during the period of the multivibrator operation caused by the coupling circuits. The cathode capacitors alternately charge up during the conducting period of the valve and discharge, through the large value resistors during its cut-off period. When the charges on the cathode capacitors are large enough to cut off the anode

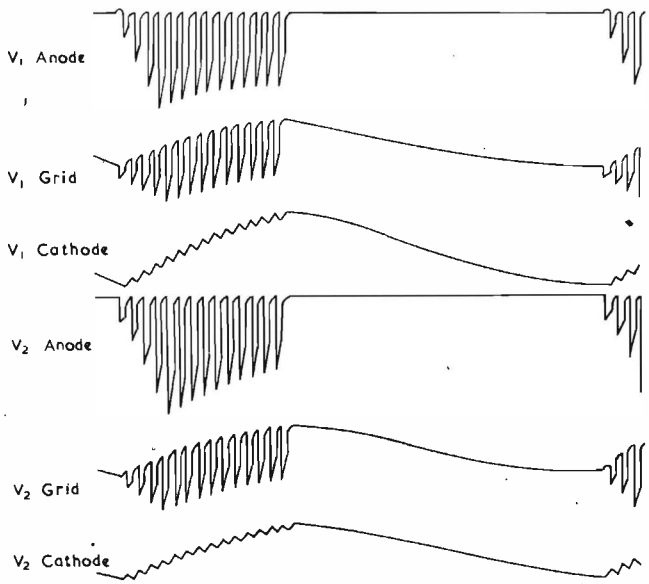


Fig. 5. Waveforms produced by circuit shown in Fig. 3, but with large values of C_1 and C_2

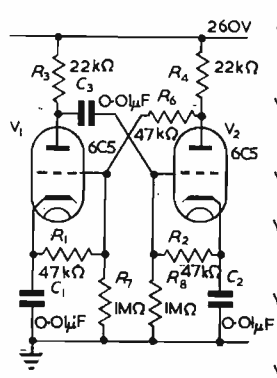


Fig. 6. New free-running multivibrator

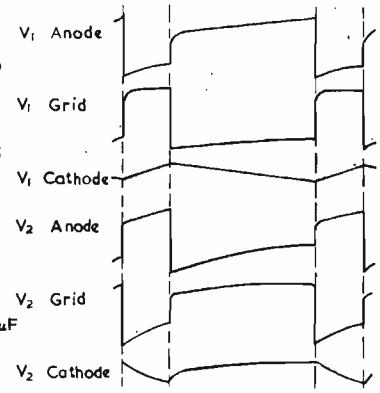


Fig. 7. Anode, grid and cathode waveforms of Fig. 6

currents, the mutivibrator action is blocked until the capacitor C_1 or C_2, discharges to the conducting point of the valve. The blocking waveforms are shown in Fig. 5.

A further circuit for a free-running vibrator is shown in Fig. 6. It uses halves of the preceding two circuits cross connected to one another and, from the explanation of these circuits its operation can be easily understood. One switching action is determined by the discharging rates of capacitors C_2 and C_3, when V_2 is cut-off. The other is mainly due to the rate of rise of potential on V_1 cathode at its cut-off time. The waveforms obtained with the component values of Fig. 6 are shown in Fig. 7.

Some Recently Developed

Cold Cathode Glow Discharge Tubes

and Associated Circuits

(Part 3)

By G. H. Hough,* Ph.D., and D. S. Ridler†

Decade Counter G10/240E

OPERATION AND DESIGN

Having briefly described some combinations of electrodes possible in a multi-electrode tube, a more detailed account will be given of the tube that has resulted from the combination of a directional cathode and a plain transfer cathode as shown in Fig. 22. This combination was selected for development because it was considered most suitable for general application.

There are, in this tube, 10 main cathodes arranged in a circle so that the 10th cathode is adjacent to the first. In between the cathodes are 10 transfer cathodes which are joined internally, and externally biased to a suitable potential. The shield electrode is taken to a positive potential

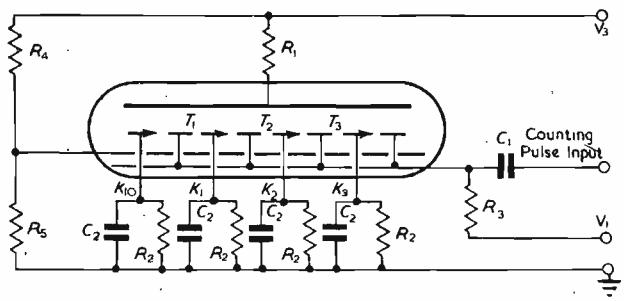


Fig. 22. The circuit arrangement for the G10/240E

derived from a potential divider across the H.T. supply. The cathodes are so designed that the transfer electrode in the forward direction is primed to a much greater extent than that in the backward direction.

The principal feature of the directional cathode is illustrated in Fig. 23 which shows the main cathode to consist of two sections. The first section is adjacent to the previous transfer cathode, under the influence of which its breakdown voltage is reduced to a figure approaching its maintaining potential. This section has a high maintaining potential relative to that of the second section and saturates at a low value of current. It is physically joined to the second part of the cathode, from which the main conduction occurs. Typical current voltage characteristics of the two sections are shown in Fig. 24 where AB is the "tail" characteristic and CD that of the "plate." The sequence of operation is that the cathode starts to conduct current on the first section and then rapidly transfers the glow to the second section, from which the forward transfer electrode is more effectively primed than the preceding one.

The transfer electrodes and cathodes are separated from each other by a distance which is less than the cathode dark space so that on establishing a discharge on any one of these electrodes a 100 per cent coupling is instantaneously provided to the adjacent electrode. By employing this type of coupling, then, the time limitations in the physical operations described are confined to the rate of spread of glow across the cathode surface and also in the transfer of the discharge from the tail of the plate of the cathode.

The length of the cathode tail determines the difference in coupled breakdown potential of the forward and backward transfer electrodes adjacent to a conducting cathode.

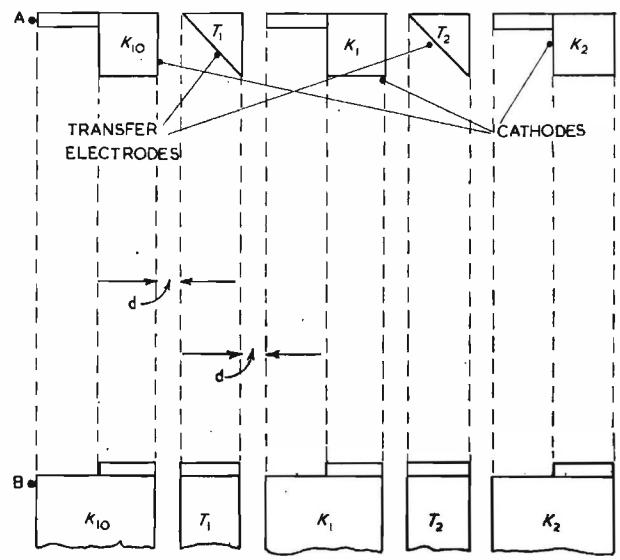


Fig. 23. The electrode geometry of the G10/240E tube

As already shown 100 per cent coupling exists to the forward transfer electrode and although some coupling exists to the one in the backward direction, its coupled breakdown potential has been designed to be never lower than 40 volts in excess of its maintaining potential.

The cathode tail area is in practice the thickness of the cathode material times the length. This area is kept at a minimum to ensure that the maintaining potential of this section of the cathode is high and that it saturates on a small value of current. Glow control plates have been introduced to prevent the glow from spreading down the sides of the "tail" section so that correct counting can be achieved.

The mechanical design of the tube is such that the electrode system consists of two sub-assemblies. The main and transfer cathodes and the shield electrodes form one assembly which is shown in Fig. 25. This figure illustrates the shape of the common transfer electrode and the way in which all the electrodes are

* *Formerly Standard Telephones & Cables, Ltd., and now De Havilland Propellors, Ltd.*
† *Standard Telecommunication Laboratories, Ltd.*

mounted on a flat mica before being clamped in position by the control electrodes. The cathode tail and plate are clearly seen in the completed sub-assembly and also the interposed triangular transfer electrodes. The anode and its locating and insulating micas form the second sub-assembly which was designed so that it can be accurately located with respect to the first. The complete structure can be placed in a closely fitting glass envelope without deleterious effects being introduced by the proximity of the

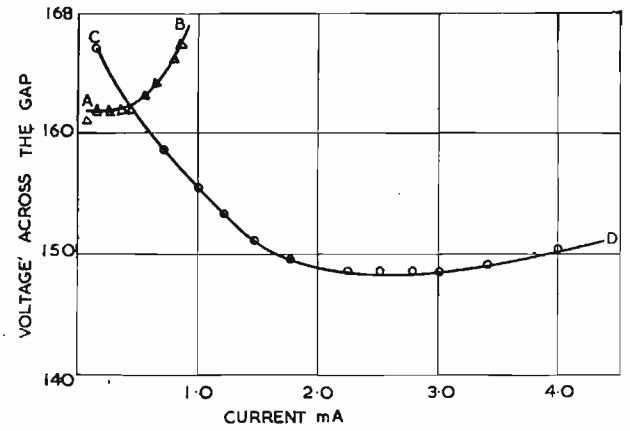


Fig. 24. The voltage/current curve for one cathode of a G10/240E tube

glass. This has been achieved by completely surrounding the cathode array by the anode, which is in the form of a cup. Suitable holes have been cut in the top of the anode so that a visual inspection of the cathode glow can be made. In addition, the glow is visible from beneath the assembly.

Due to the circular construction, the glow can be made to rotate continuously if the transfer cathode is fed with a continuous train of pulses. In a 10-point tube, any one cathode thus provides a single pulse out for every 10 applied to the tube.

The Transfer Mechanism

To determine the exact mechanism of the transfer of the glow from one main cathode to another via a transfer cathode, a detailed examination was made in which the currents flowing in the various electrodes in the tube were measured at different points in time. From this examination, it was shown that there are three modes in which the transfer can be effected.

Mode 1 is that previously described and illustrated in Fig. 20 and is the normal mode of operation. A negative counting pulse fires the transfer cathode, and its amplitude should be sufficient to extinguish the first cathode and to reduce the potential across all other anode-cathode gaps to below the maintaining potential of all other cathodes. At the trailing edge of the negative pulse the anode potential rises, and on reaching the maintaining potential of the next cathode is caught and held at that level, at the same time extinguishing the transfer-cathode discharge. This condition requires the transfer cathode to take a current that is in excess of the current conducted by the gap that is being extinguished, and thus demands a relatively large transfer current.

Mode 2 is a modification of the previous one, and is associated with a reduction of the amplitude of the pulse supplied to the transfer cathode. Firing the transfer cathode now extinguishes the previous cathode, but the total current taken by the transfer cathode is insufficient to reduce the voltage on the anode to a point below the maintaining potential of the next cathode in the array, so that during the transfer pulse the next cathode starts to conduct. Here again, the transfer cathode takes current that is equal to, or in excess of, the main-gap current.

Mode 3. In this case the transfer cathode is fired by a small pulse, which reduces the current flowing in the previous cathode but does not extinguish it. The anode potential does not fall more than about 15 volts, so that when the next cathode is primed by the transfer cathode, there is a high enough potential across the gap to fire it. When it fires, the initial peak current taken to charge the capacitor in its resistance-capacitance circuit extinguishes the previous cathode by dropping the anode voltage. Therefore, the transfer cathode conducts a small amount of current, which may be less than that taken by the main cathodes, but which has to be large enough to cover the transfer cathodes with glow, and thus primes the forward adjacent cathode.

To summarize the three modes in terms of pulse amplitude and high-tension supply voltage, the following very general conditions exist:

Mode 1. High pulse amplitude and medium and low anode supply voltage.

Mode 2. Medium pulse amplitude and medium and low anode supply voltage.

Mode 3. Minimum pulse amplitude and high and medium anode supply voltage.

Assuming an operating range of 60 volts on the high-tension supply, the terms low, medium and high might correspond to 20-volt steps.

Operating Limits

The minimum high-tension supply is determined by the minimum current necessary to establish a stable forward-priming discharge. The maximum high-tension potential is fixed by the maximum current a cathode can take before a second cathode breaks down in the absence of a pulse. This range is generally in the region of 300 to 360 volts, but is determined partly by the choice of circuit components.

The following are typical operating conditions for the type of tube described for a frequency range of 0 to 5kc/s:

H.T. Supply Voltage	330V ± 20.
Transfer Electrode Bias	75V nominal (Derived from potentiometer of 56Ω and 15Ω from H.T. supply).
Cathode Resistor	15kΩ
Anode Resistor	27kΩ
Cathode Capacitor	0·005μF.
Pulse Amplitude	130V ± 20.
Pulse Width	16 ± 4 microseconds.
Shield Electrode Bias	120V nominal (Derived from potentiometer of 56kΩ and 30kΩ from H.T. Supply).

The component tolerances are all ± 5 per cent

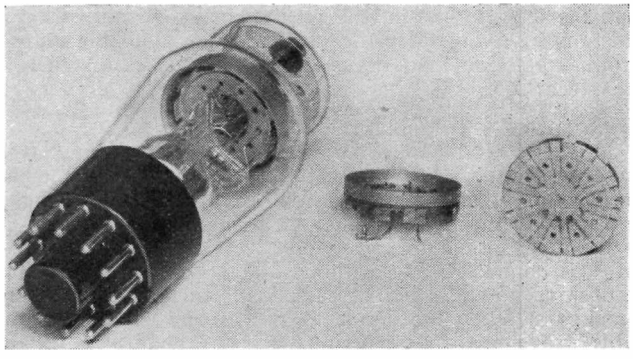


Fig. 25. The G10/240E electrode structure

Under all conditions the voltage output developed across the cathode resistor is greater than 40 volts. This enables the tube to be used in conjunction with the G1/370K, referred to previously, in straight scaling circuits in which the trigger tube is used as a gate between successive stages.

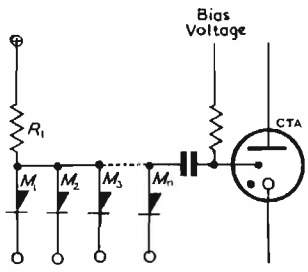


Fig. 26. A simple coincidence gate circuit for operating a trigger tube

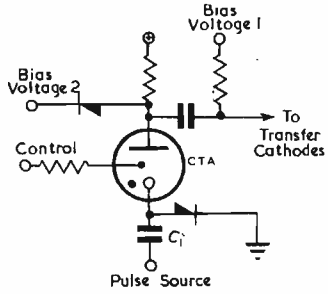


Fig. 27. A gate circuit using a trigger tube

Circuit Application

GENERAL

Practical applications of the G10/240E counting tube and the related G1/370K high speed trigger tube have given rise to a number of circuits which are of general interest. For instance, while the choice of 10 as the scale most likely to satisfy the majority demand was probably correct, occasions arise when a number greater or less than ten may be desired. In these circumstances it is generally more economical to adapt the G10/240E than to develop a new tube type. Again the binary code configuration in Fig. 21(f) can result in a complicated tube if more than a few code elements are used and the same effect can be more easily obtained by using a combination of G1/370K and G10/240E tubes.

The view has been taken that the gas tube has an inherently more predictable life than the hard tube and that its characteristics are well suited to counting applications. In many cases, therefore, the G1/370K would be used where otherwise a pentode or double triode might do. The operating characteristics of the counting tube and the trigger tube have been designed for interworking; the supply voltages are the same and the available output from a cathode load of either type is at least sufficient to trigger a G1/370K.

COINCIDENCE GATE CIRCUIT

In some of the more complex circuits involving large numbers of the two types of tube working together, it has been found that the most useful circuit for combining a number of positive outputs occurring simultaneously is that shown in Fig. 26. The positive side of each rectifier M_{1-n} is connected to a cathode load. Only when there is a positive potential across each load will all the rectifiers block and allow the anode to rise at the common point. This rise can then be used to trigger the biased trigger tube CTA. In this so-called coincidence circuit, the value of R_1 and the stray capacitances determine the rate at which the common point potential rises and hence the ultimate speed at which the circuit can be made to operate.

COUNTING PULSE CONTROL CIRCUITS

In practice, the transfer electrodes of a counting tube are seldom connected directly to the pulse source, because the need arises for a circuit by which the pulses are admitted to the tube under a controlling potential. Two requirements of such a circuit are firstly that the controlling lead shall have a high input impedance and secondly that the counting pulse connected to the transfer electrodes shall appear from a low impedance.

The circuit used for this purpose essentially uses the main gap of a G1/370K trigger tube to pass a pulse without loss of power when a positive potential on the trigger initiates a discharge. Fig. 27 shows the arrangement. Negative pulses of controlled amplitude and width are applied to the cathode capacitor C1. The pulse amplitude is several volts less than the normal trigger to cathode breakdown potential of tube CTA so that with the trigger at earth potential, the gap will not break down. On the other hand, when the cathode pulse coincides with a positive potential on the trigger the gap will break down and the main gap conduct. In consequence the negative pulse will appear at the anode. The value of the normal standing anode potential derived from the bias supply is arranged to be too low to maintain a discharge so that the gap extinguishes on the trailing edge of the pulse. The anode resistor is returned to a high positive potential to ensure that the coupling capacitor discharges rapidly after a pulse.

SCALE-OF-1,000 DIVIDER

Fig. 28 shows a circuit of three tubes arranged to operate

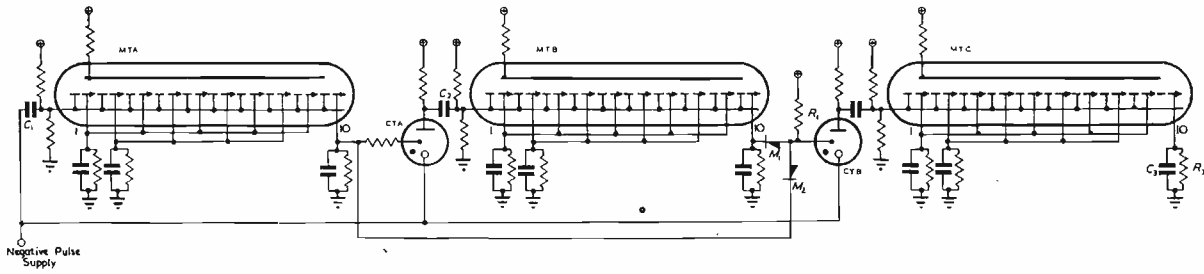


Fig. 28. A circuit for coupling three G10/240E tubes together to form a scale-of-1000 counter

in decade illustrating one use of the last two arrangements. The first multi-cathode tube MTA is supplied with negative going pulses through C_1. Since only one cathode is used for an external function, the first 9 main cathodes use only two resistance-capacitance networks and the 10th is connected to the trigger of the pulse control tube CTA Sufficient potential to break down the trigger cathode gap of this tube only occurs with a combination on the trigger of a positive pulse from the counting tube and a negative pulse from the supply lead on the cathode and therefore only each 10th pulse is passed through CTA and C_2 to tube MTB, which operates in response. Every hundredth pulse is gated to the third tube MTC through gate tube CTB, which is controlled by the last cathodes of MTA and MTB by means of the rectifier coincidence network comprising R_1, M_1, and M_2. The output from the network R_2C_3 represents a division by 1,000 of the original pulse supply. Further stages can be added to give higher

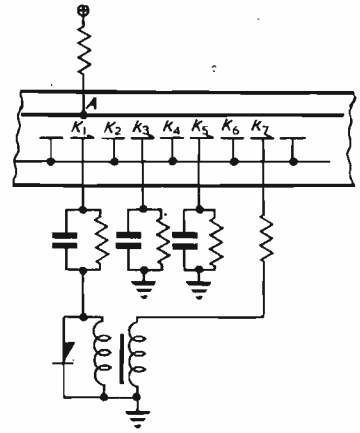


Fig. 29. A circuit using the G10/240E to count less than 10. This illustrates how the discharge can be restored to a "home" cathode

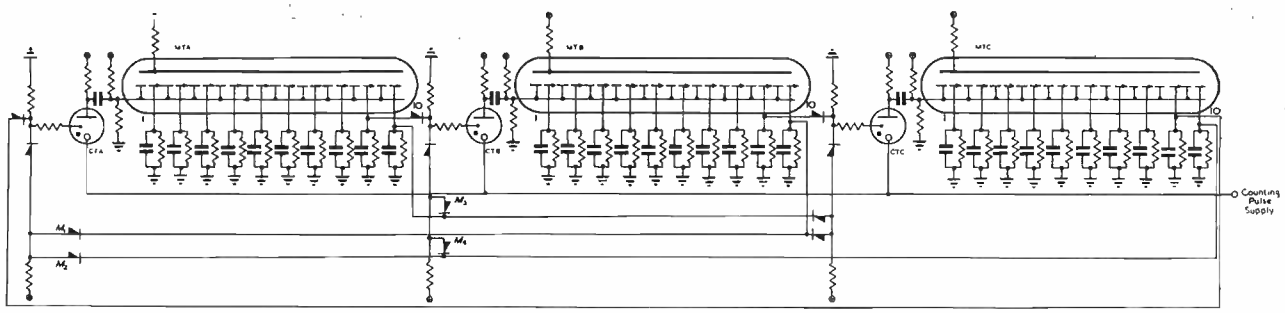


Fig. 30. A circuit using three G10/240E tubes to count 27. This arrangement provides 27 separate outputs

orders of division, the limiting factor being the rectifier coincidence networks.

Counting Less Than 10

The most general method of resetting the G10/240E, apart from completely disconnecting all unwanted cathodes, is to insert a rectifier in series with the cathode with the positive side facing earth and to apply a negative pulse to the negative side with sufficient amplitude to breakdown the associated gap. If the tube itself produces a resetting pulse from a suitable cathode, counts of less than ten can be achieved.

Fig. 29 shows a section of a tube wired for a count of three. The discharge moves normally under the influence of the pulse supply from cathode K_1 until cathode K_3 is reached. The next pulse transfers the discharge to K_7 at which stage the current in the primary of T_1 induces a negative pulse in the secondary which in turn breaks down the gap AK_1 extinguishing the AK_7 gap. A subsequent pulse moves the pulse to K_3 and the cycle is repeated.

There is a further method available if the counter is used with a pulse control tube and if the incidence of counting is slow compared with the applied pulse rate. This condition might arise for instance, in the stages of a divider of the type described other than the first. If a smaller count were required the positive output from unwanted cathodes would be connected back to the pulse control tube and the additional pulses would cause the discharge to "skip" over unwanted cathodes.

This latter technique is suitable in the successive stages of a frequency divider for scales of 9, 8, 7 and 6. For a scale of 5, every cathode can be connected to the fifth one along, i.e. its opposite number in a ring counter, making effectively a five-point tube. For counts lower than 5, an appropriate number of G1/370K tubes is probably more economical.

Counting more than 10

For counts greater than ten it is usual to add either additional G1/370K tubes or G10/240E tubes dependent on the precise count required. The effective number of cathodes on each multipoint tube is reduced from 10 to 9, since it is necessary to use one cathode as a rest position. The circuit illustrated in Fig. 30 represents a 27-point distributor. To follow the sequence of operation, assume that tubes MTB and MTC are initially discharging on their 10th or rest cathodes and that tube MTA is discharging on its first cathode which represents the first outlet of the 27-point distributor. Rectifiers M_1 and M_2 are blocked by the discharge potentials from tubes MTB and MTC and the trigger of gate tube CTA is therefore held positive. Before this gating potential is removed, 8 successive pulses will move the discharge to cathode 9 on MTA priming the trigger of the second gate tube CTB so that the 9th pulse steps both counter tubes MTA and MTB. The blocking potential to M_1 is removed, but the 10th-cathode discharge potentials on MTA and MTC block M_3 and M_4 so that now tube MTB responds to the next 9 impulses gated through tube CTB. In a similar manner tube CTC gates a following set of 9 pulses and so on to tube CTA to start the cycle a second time. Again any number of tubes may be operated in series dependent only upon the characteristics of the rectifier networks.

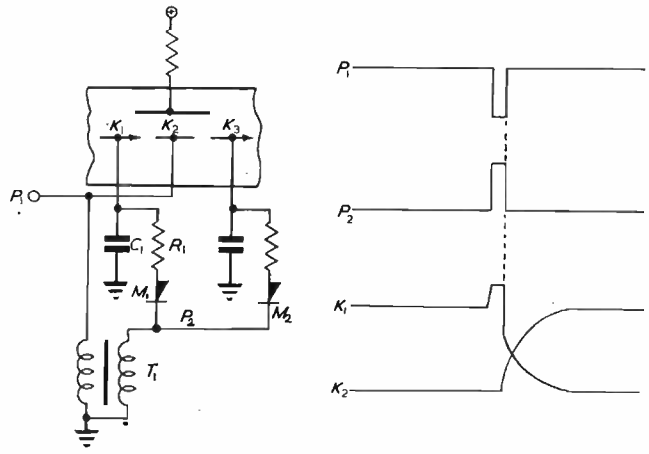
High Speed Operation

The G10/240E has been designed primarily for operation in the frequency range 0-5,000c/s. Higher speeds are possible however if a special circuit is used. The difficulty with the normal method occurs because, even at minimum pulse width, the cathode time-constant cannot be indefinitely reduced if the cathode capacitor is to retain sufficient charge at the end of the pulse to ensure forward transfer. As a result a full decay or rise in potential cannot take place and, although the discharge may transfer correctly, the outputs may overlap and be unusable. At the considered limit of 5,000c/s using a cathode time-constant of 75 microseconds, the cathode potential decays to about 0·3 of its maximum value at the trailing edge of a pulse and to just over 0·1 by a subsequent pulse.

The method of using the tube up to its physical limit in speed depends on being able to stop the cathode capacitor discharging while the pulse is on. This allows a considerable reduction in time-constant.

Fig. 31 shows the precise arrangement. Assume that K_1, K_2 and K_3 are cathodes in a section of counting tube and that the first gap is discharging. The transformer T_1 inverts the counting pulse and applies the resultant blocking potential to the rectifiers M_1 and M_2 so that no current flows from C_1 while the pulse is on. After the pulse, the time-constant R_1C_1 has only to keep K_1 elevated while the discharge is established on K_3, a process which takes only a few microseconds. It will be appreciated that the output from K_1 increases when the pulse is first applied during the time taken for the transfer gap discharge to establish. In this time the cathode rectifier blocks and capacitor C_1 charges still further through the anode lead increasing the available output.

Fig. 31. A circuit for high speed operation using the G10/240E



Conclusions

Some of the new types of tubes described are now available and a variety of equipment using specialized circuit techniques has undergone field trials, these have shown promise of reliability and ease of maintenance to be possible in complex circuits.

Progress on further developments has been such that already a modified version of the G10/240E is in production which is smaller, single ended and superior in performance. Also there is little doubt that new tube types and new circuits will follow, which will give improved performance and increase margins.

Acknowledgments

The authors wish to express their thanks to Standard Telephones and Cables Ltd., for permission to publish this paper, and to their many colleagues who have assisted in its preparation, particularly Mr. T. M. Johnson and Mr. A. B. Odell who have taken part in the work described herein.

A Direct Reading Mains Frequency Cycle Counter

By P. Huggins,* A.M.Brit.I.R.E.

WHERE it is desired to measure (or check) timing of certain industrial processes, and the accuracy required precludes the use of a stop watch, a "cycle recorder" is often employed. In this a 50c/s supply fed into the apparatus vibrates the stylus at this frequency and paper travelling at a uniform rate beneath the stylus, therefore, receives a sinusoidal imprint. To check the time it is necessary to count, or gauge, the number of cycles recorded.

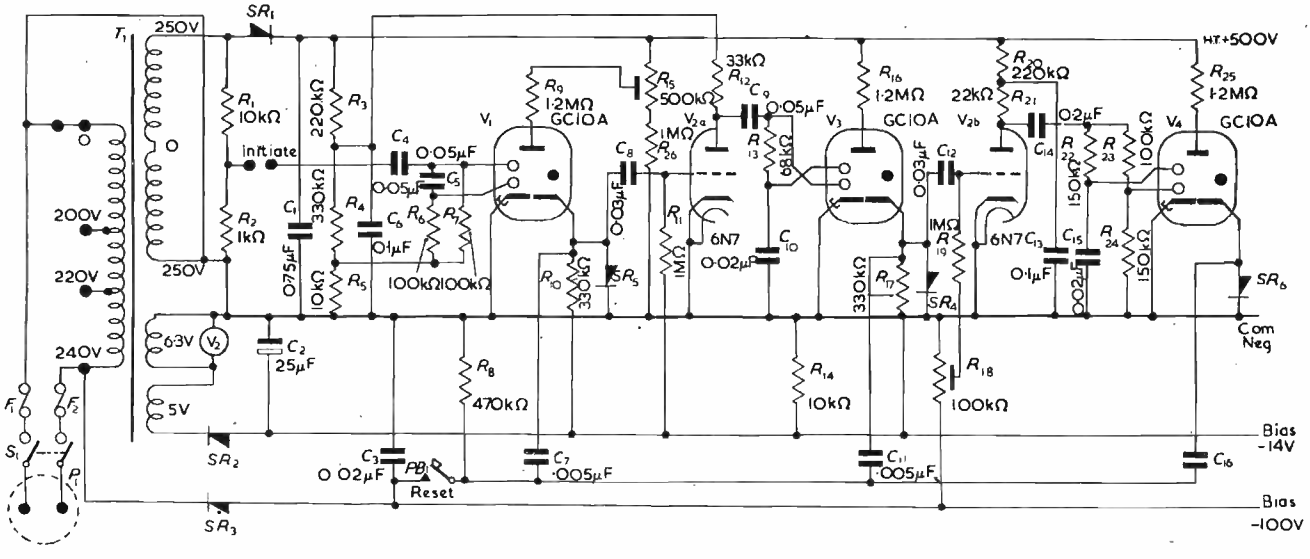
By applying the recently introduced Dekatron technique[1] to this problem, it is possible to develop a decade cycle counter covering the time range ·02sec to 20sec, which can be read at a glance. It is mains operated.

From an operational point of view the counter is very simple. Three Dekatron tubes project through three escutcheons, each engraved 0-9. These represent "units", "tens", and "hundreds" of cycles respectively. A "reset" push-button causes the glow discharge of each Dekatron to come to rest under the "0" on each escutcheon. On connecting together the "initiating" pair of leads, the glow discharge within the "units" Dekatron commences to revolve in a clockwise direction: i.e., the timer is counting cycles at the mains frequency. When the glow discharge has completed one revolution on the "units" tube, the "tens" Dekatron moves from 0 to 1: on the second revolution it moves from 1 to 2, . . . and on the tenth revolution the "hundreds" Dekatron moves round to position 1, etc. When the "initiating" pair of leads are re-opened (at the end of the timed period) the glow discharge will permanently lock in whatever position they are then located. Thus the timed period can be read (in cycles at 50c/s) directly to an accuracy of 1/50 second. The valves employed are three GC10A Dekatrons and a 6N7 double triode. The power rectification circuit is conventional and uses a standard commercial radio transformer. Metal rectifiers are employed, and there is little smoothing on the H.T. line. (See Fig. 1).

Approximately 40V A.C. is fed into the "units" Dekatron (V_1) from the R_1 and R_2 network when the "initiating" leads are closed. This sinusoidal E.M.F. is applied through C_4 to the second guide, and through a phase advancing capacitor (C_5) to the first guide. A small positive polarizing potential (of the order of 4V) is fed to both guides from the network R_3, R_4, and R_5. This concentrates the glow on the cathode when quiescent. The sinusoidal input is thus able to to drive the first and second guides sequentially negative to the anode, and force the glow around the tube. When the glow rests on the

* *Sciaky Electric Welding Machines Ltd., Slough.*

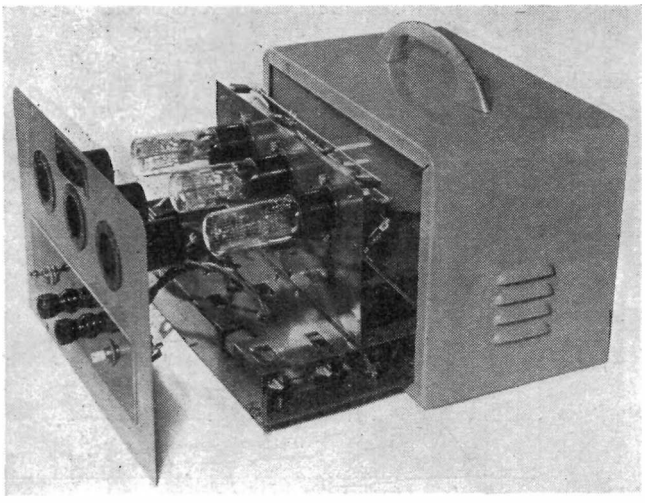
Fig. 1. Circuit diagram of the mains frequency cycle counter



output cathode (i.e., the "0" one), current flows through R_{10} producing a positive voltage of about 25V peak above common negative potential.

When counting, the duration of the transitory charge on the output cathode is of one cycle duration, and its repetition rate is 5 p.p.s. So V_{2a} may be considered as a "class C" L.F. amplifier that is driven from below cut-off on receipt of each pulse.

Its anode load resistor (R_{12}) is the driving source for the "tens" Dekatron.



The complete instrument

Because of the 180° phase reversal effected by this triode, the guides of V_3 receive a negative pulse every ten cycles. This pulse is resistance-capacitance coupled to guide 1, and coupled via a quasi-integrating network ($R_{13}C_{10}$ to guide 2. Hence the guides are sequentially fired and the glow discharge moves around to the successive cathodes.

The second amplifier stage is merely a replica of the first, except that it is biased further beyond cut-off to obtain a peakier pulse. Thus large values of capacitors in the successive Dekatron stage (which, of course, is operating at $\frac{1}{2}$ p.p.s.) are eliminated.

V_4 is also merely a repetition with slight modification, of the V_3 circuit.

The "zero reset" is obtained by applying a short duration negative voltage to all three Dekatron output cathodes. On depressing the push button (PB_1) a D.C. potential of about −100V is applied, (via coupling capacitors), to R_{10}, R_{17} and R_{26} simultaneously, and so all output cathodes are momentarily very negative to their anodes, thus investing the glow discharge on these cathodes. There is a tendency, on opening PB_1, for the discharge of the coupling capacitors to be magnified by the amplifiers and, in consequence, trigger the succeeding Dekatron round one step. Small rectifiers between the "zero" cathode and H.T. negative, by-pass these pulses and ensure that the glow will remain on the correct cathode until re-initiation.

While this device has been designed to indicate the passage of time, its accuracy is, of course, dependent upon the mains frequency; but this is an improvement on capacitor charge timing systems whose accuracy is dependent upon the mains voltage stability. Should greater precision be required, it could be arranged to have, say, a crystal oscillator and frequency divider chain, to provide the driving sinusoid.

Further stages could, of course, follow V_4 to extend the range of the equipment.

Acknowledgment

The author wishes to thank Mr. R. W. Ayers, Managing Director of Sciaky Electric Welding Machines, Limited, Slough, for permission to use photographs, and circuit design developed for the Company. Also Mr. Harry Pratt, who sowed the first seed and was responsible for the neat layout.

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A NEW RADIO TELESCOPE

THE Government, through the Department of Scientific and Industrial Research, and the Nuffield Foundation have decided jointly to provide a steerable radio telescope for Manchester University. The total cost is expected to approach £336,000, half of which will be paid by the Nuffield Foundation and half borne on the vote of the D.S.I.R.

Since the war the techniques of radar and radio, applied to astronomy, have yielded a series of discoveries about the universe. In this field of radio astronomy the pioneering work of research scientists at Manchester and Cambridge Universities has given Great Britain a prominent position. This work has been financed in the past both by the D.S.I.R. and the Nuffield Foundation. In 1945 the Foundation made a five-year grant to the Physics Department at Manchester University, part of which was used to develop research in radio astronomy at an experimental station at Jodrell Bank in Cheshire. In 1947, D.S.I.R. began, from its money voted by Parliament, to support the work both at Manchester and Cambridge. At Cambridge important results have been obtained using interferometric methods, while at Manchester a fixed radio telescope (a fixed paraboloid aerial), 220 feet in diameter, has been used to pick up radio waves reaching the earth from sources as far distant as the great spiral nebula of Andromeda, 750,000 light years away. At both universities radio waves have been recorded from sources in space which do not coincide with known visible stars and existence of these sources has presented an interesting puzzle.

The present fixed radio telescope at Jodrell Bank, though the largest in the world, is inadequate to carry this research to all regions of the sky. Manchester University therefore asked the D.S.I.R. for a substantial grant to pay for a large steerable radio telescope, which could be directed at will to scan any part of the sky or to follow the course of any particular star, and could also be used for research on meteors, aurorae, the sun, moon and the planets.

The aperture of the new radio telescope will be little larger than the fixed one at Jodrell Bank; it will be completely steerable and will be able to transmit or receive signals from any part of the sky.

The diameter of the paraboloid aerial will be 250 feet. The diameter of the platform on which the radio telescope will rotate will be 310 feet.

The height, to the top of the horizontal axis, will be 185 feet. When the beam from the aerial is horizontal the total height will be 300 feet. The total weight of the radio telescope carried on the rails will be 1,270 tons.

It will be used in all aspects of radio astronomy. The priority programme will be to continue the study of the galactic and extra galactic emissions with particular reference to the number and nature of the dark radio stars. It will also be used to plot the intensity of the radiation, particularly from those important regions of the Milky Way system which are obscured from normal vision by the great dust clouds in interstellar space. As and when this urgent programme permits, the instrument will then be applied to the solar and terrestrial studies, to meteors, the moon, and perhaps the study of the nearer planets. It is anticipated with confidence that this instrument will do for radio astronomy what the large telescopes in America have done for classical astronomy.

The construction of the telescope should commence this summer and it is hoped that it will be completed within four years.

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

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

ALTHOUGH detailed investigations have been carried out recently to determine the variations in the characteristics and the limitations of glow-discharge voltage-regulator tubes[1-9] it appears that very little information is available on the noise characteristics of such tubes. The only figures published are to be found in a few tube specifications but here a single value is usually quoted. Many tube specifications make no mention of noise characteristics. No idea can be gained from the small amount of published data, of the variations in noise with tube current, from tube to tube of similar or different designs, from operation to operation with a single tube, with life or with effective load. The authors have recently examined several tubes of 15 different types to provide this information. The present article is confined to measurements of peak-noise. It is hoped to publish the results of mean-noise measurements in the near future. The tube types tested are: 85A1, 85A2, 7475,

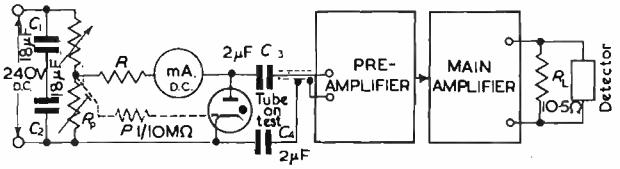

Fig. 1. The circuit used for test
Primer circuit for G180/2M tubes shown dotted

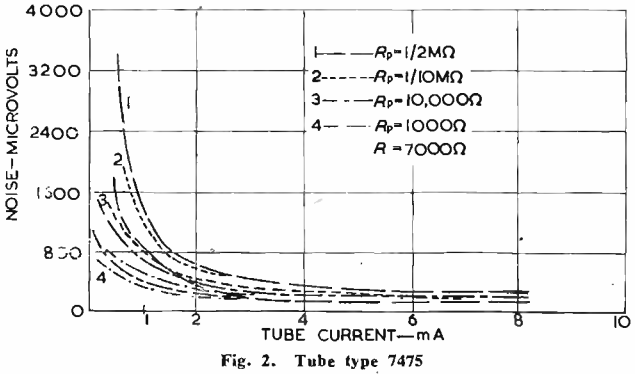

Fig. 2. Tube type 7475

CV188, VS70, CV71, KD60, QS83/3, G180/2M, NT2, CV1199, CV284, VR150, VR105 and S130. In many cases the tubes of a particular type were not all from the same batch or of the same construction because they were obtained over a period of two years and modifications were made by the manufacturers from time to time.

Procedure

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

Results

The peak-noise characteristics of almost-new tubes of several types are shown in Figs. 2 to 6, and for the other types tested the noise limits for minimum and maximum current are given in Table 1. In all the cases illustrated it will be seen that the tube current has been reduced

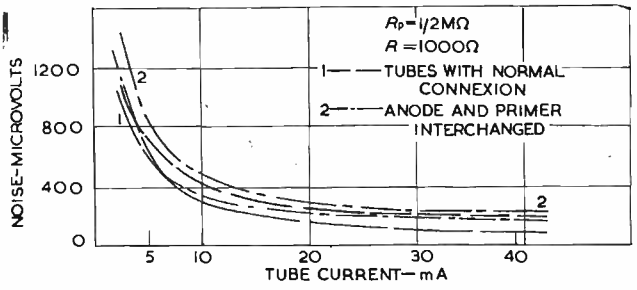

Fig. 3. Tube type G180/2M

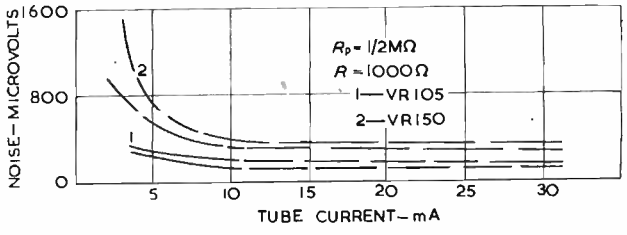

Fig. 4. Tube types VR105 and VR150

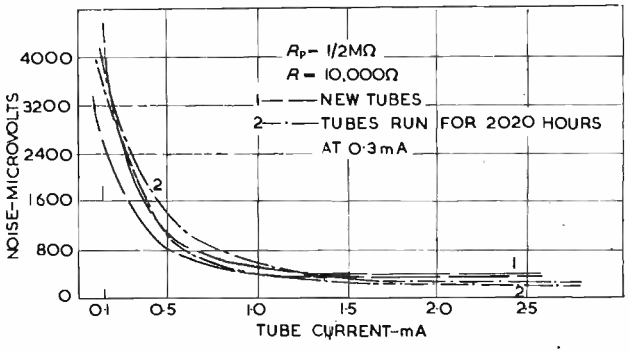

Fig. 5. Tube type KD60

below the specified minimum value and the noise recorded. For each tube the peak-noise was noted for several operations. Thus, a very large number of readings have been obtained for each type of tube and, in order to make the Figures clear, only the limits have been drawn. Variations of peak-noise characteristics with life have been determined for 5 tube types, namely, 7475, 85A1, 85A2, QS83/3 and KD60. Figs. 5 and 6 show these variations for types KD60 and 7475 respectively. No

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similar curves have been drawn for types 85A1 and 85A2 because they show practically no change of peak-noise with life (at least up to 18,560 hours for 85A1 and 5,400 hours for 85A2). QS83/3 tubes behave in a similar manner to type KD60 so no curves are shown for these either. Fig. 3 shows the effect on the noise characteristics of interchanging the anode and primer electrodes of G180/2M tubes.

Discussion of Results

It is found that the noise characteristics of all tubes, at any stage in their life, follow the same general form, that is, the noise increases with decreasing tube current. The noise increases rapidly as the region of minimum

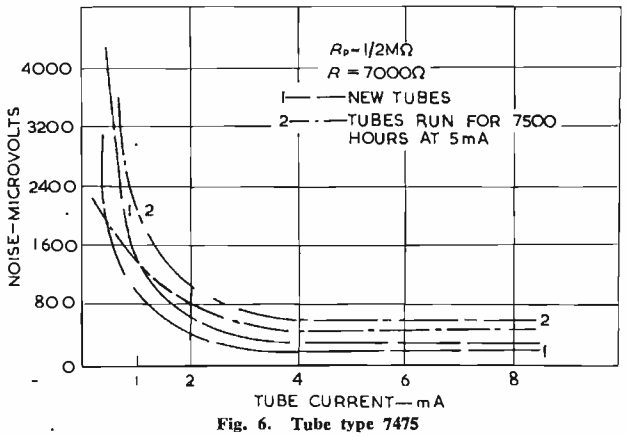

Fig. 6. Tube type 7475

TABLE 1
Peak-Noise Limits for Various Types of Tube

Tube Type	Value of Resistor R (Fig. 1) Ohms	Approximate Peak Noise Limits (mV.) with Rp=0.5MΩ	
		At Minimum Specified Tube Current	At Maximum Specified Tube Current
85A1 ..	7,000	0.84–1.1	0.12–0.16*
85A2 ..	7,000	0.73–0.91	0.12–0.16
CV188 ..	7,000	0.71–1.31	0.22–0.36
VS70 ..	7,000	0.82–1.09	0.17–0.20
CV71 ..	7,000	2.87–3.24†	1.20–1.48
QS83/3 ..	10,000	0.95–1.00	0.24–0.31
NT2 ..	10,000	1.93–2.51	0.38–0.60
CV1199 ..	425	0.09–0.20‡	0.06–0.12‖
CV284 ..	10,000	0.22–0.33	0.07–0.11
S130 ..	1,000	0.25–0.35§	0.05–0.11§

* At 8mA. † At 1mA. ‡ At 20mA. ‖ At 100mA.
§ Erratic values up to 2.8mA recorded in the current range when the cathode glow was moving about.

current is approached. The characteristics for a given tube are found to be nearly reproducible although with the S130 tubes, large erratic values of noise are found during times when the cathode-glow is moving about.

The variations in the peak-noise characteristics from tube to tube of a similar design are not very great, in fact the variations from type to type are less than might be anticipated from the information given in specifications and from the previous work on other tube characteristics. This also seems rather surprising in view of the widely different constructions, gas fillings, gas pressures and electrode materials used. It is interesting to see from Fig. 3 that for the G180/2M tube the peak-noise is increased by interchanging the anode and primer electrodes.

The effect of varying resistor R_p (Fig. 1) on the noise characteristics of tubes, types 85A1, 85A2, 7475 and NT2 has been determined. In all cases, particularly at low tube currents, the noise is reduced as the value of R_p drops as can be seen for type 7475 tubes from Fig. 2. Thus, it is necessary, in quoting noise figures, to give also the value of the effective load presented to the noise voltage.

As stated in the previous Section, 85A1 tubes run for 18,560 hours at a constant current of 5mA and 85A2 tubes run for 5,400 hours at the same current show practically no change of noise characteristics with time.

Fig. 5 shows the noise variations with time for KD60 tubes which were run for 2020 hours at 0.3mA. QS83/3 tubes were also tested after they had been run for 2,240 hours at 3mA. In both cases the tubes were still functioning satisfactorily as regulators, with their running voltages inside their respective specified running-voltage limits. It is interesting to note that for these tubes the noise has decreased at high currents with life and increased at low currents while over a small current range, for each tube the noise is practically the same as when the tube is new.

The noise variations with life for some 7475 tubes which were run continuously for 7,500 hours at approximately constant currents of 5mA are shown in Fig. 6. At the end of this time the tubes were useless as regulators, both the striking and running voltages having increased to values well above the specified maxima. It will be seen from Fig. 6 that the noise values have also increased a good deal during this time. The variations in noise from tube to tube and from operation to operation of a single tube have also increased considerably. Though these life-tested tubes are of a different batch from those which were nearly new when examined, previous results show that the peak-noise values for the two batches can be compared.

Conclusions

It seems that a careful revision should be made of all tube specifications giving any information on noise characteristics, and, those which do not give any, should now include it. It would be of great value if the specifications could be modified to quote the approximate limits for both peak and mean noise voltages to be expected throughout the current range of a tube. It should be remembered, however, that the value of the load presented to the noise voltage should always be stated. It has already been mentioned that the authors have measurements now in progress to determine the mean-noise characteristics of tubes and it is hoped to publish the results of the work shortly. The work is being carried out with essentially the same equipment.

Acknowledgment

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

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Feedback in Time-base Circuits

By A. E. Ferguson*, M.E.E., A.M.I.E.Aust.

THE generation of a voltage which increases as a linear function of time is widely used for the horizontal deflexion of a cathode-ray tube spot to provide a linear time sweep. A simple method of obtaining approximately linearly rising voltages is to charge a capacitance connected to a fixed potential through a series resistance. The capacitor voltage as a function of time is then given by:

$$C = E(1 - \epsilon^{-t/RC})$$

where E = charging potential,

R = series resistance,

C = capacitance.

During the initial stages of the charging, the capacitance voltage changes almost as a linear function of time.

While such a circuit has the benefit of the utmost simplicity, in the majority of applications there is a need for some improvement in the linearity. Many and varied circuits have been used for effecting this. The methods may be grouped into two main sections as follows:

(a) Circuits which use compensating networks either in shunt or in series with the exponential voltage function obtained above,

(b) Circuits which use an amplifier and feedback as a part of the voltage function generator.

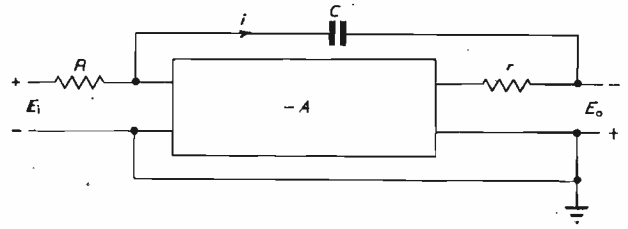

Fig. 1. Basic Miller time-base

The latter group includes the Miller type time-base circuits and the so-called constant-current pentode time-bases. It is the purpose of this article to discuss these two circuits and to show that they are fundamentally very similar.

Miller Time-Base

The basic Miller time-base circuit is shown in Fig. 1.

An amplifier of internal voltage gain $-A$ and equivalent series output resistance r has a capacitance C connected between its input and output terminals. An input voltage, usually a step function derived from external trigger circuits, is applied to the amplifier through the series resistance R, at time $t = 0$.

If the input circuit of the amplifier is assumed to draw no current, then:

$$E_o + E_i = Ri + \int i dt/C \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$-A(Ri - E_i) = E_o + ri \quad \ldots\ldots\ldots \quad (2)$$

where E_i = input voltage which is assumed constant for $t > 0$,

E_o = output voltage of the time-base,

i = network current, assumed positive direction as shown in Fig. 1.

Eliminating E_o from these equations and differentiating i with respect to time gives:

$$di/dt + \frac{i}{C(R(1 + A) + r)} = 0$$

$$\text{i.e., } i = i_o \, \epsilon^{-\frac{t}{C(R(1 + A) + r)}}$$

hence $E_o = -i(r + AR) + AE_i$ from (2)

$$dE_o/dt = \frac{(r + AR)i_o}{C(R(1 + A) + r)} \, \epsilon^{-\frac{t}{C(R(1 + A) + r)}} -$$

$$\approx (I_o/C) \, \epsilon^{-\frac{t}{C(R(1 + A) + r)}}$$

for $A \gg 1$.

Constant Current Pentode

In a pentode the plate current is relatively independent of the plate potential for given screen grid and control grid

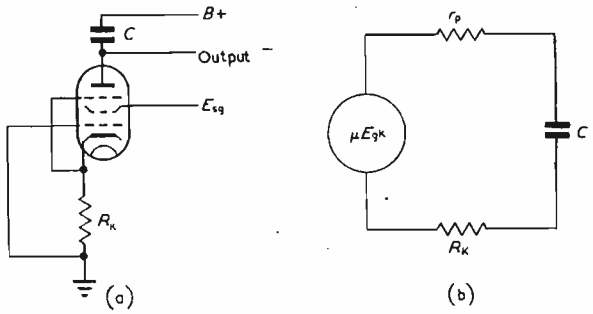

Fig. 2. Pentode time-base with feedback across the cathode resistor

biases. By charging a capacitance in the plate circuit a good approximation to a linear voltage function is obtainable. Some further improvement in the linearity is possible if a feedback voltage is developed across a cathode resistance as shown in the circuit of Fig. 2(a).

The equivalent circuit of this is shown in Fig. 2(b) which assumes the screen grid to cathode potential is maintained constant. (The practical application of this circuit is not limited to pentodes, as will be seen a triode valve is also quite effective).

$$e_{gk} = -i_p R_K \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$\mu e_{gk} = i_p(R_K + r_p) + \int i_p dt/C \quad \ldots\ldots\ldots \quad (4)$$

which give, eliminating e_{gk}

$$di_p/dt + \frac{i_p}{C(r_p + R_K(1 + \mu))} = 0$$

$$\text{i.e., } i_p = i_{po} \, \epsilon^{-\frac{t}{C(r_p + R_K(1 + \mu))}}$$

Also $E_o = B + - i_p dt/C$

$$\text{hence } dE_o/dt = (-i_{po}/C) \, \epsilon^{-\frac{t}{C(r_p + R_K(1 + \mu))}}$$

* University of Melbourne.

Conclusions

It will be seen that the form of the expression for the rate of change of the output voltage of each circuit is similar when:

$$|A| = |\mu|$$
$$r = r_p$$
$$C = C$$
$$R = R_K$$

If the pentode of the second circuit were used as the Miller valve in the first circuit then it would be possible to make:

$$C = C$$
$$R = R_K$$

but, since the Miller amplifier would require a plate load to pass D.C. then:

$$|A| \leqslant |\mu|$$
$$r \leqslant r_p$$

Hence for similar components in the time-constant network and a similar valve, the Miller circuit would be slightly inferior. The difference, however, is scarcely more than of academic importance.

The chief difference between the two circuits lies in the smaller internal impedance of the Miller circuit. If a resistive load R_L is placed across the output of the Miller circuit the effect may be considered using Thevenin's theorem to replace the amplifier output network by an equivalent voltage generator and series resistance. It will have the effect of reducing r and A, the smaller R_L the greater the reduction in each.

$$r' = \frac{rR_L}{R_L + r}$$

$$A' = \frac{AR_L}{R_L + r}$$

where r' and A' are the equivalent values of r and A when R_L is applied. Its effect is negligible if $R_L \gg r$.

In the second case, however, a load R_L across the output is directly in shunt across the capacitance C, and in order to have negligible effect it must be considerably greater than $(r_p + R_K(1 + \mu))$.

In a practical circuit with typical values of components it is possible to follow the Miller valve with an amplifier without causing an appreciable change in the operation of the circuit. This is not the case when using the second class of circuit.

It would appear therefore that the real superiority of the Miller time-base circuit lies in its much greater linearity when loaded by a shunt circuit such as the input resistance of a deflexion amplifier. If, however, the X plate of the cathode-ray tube were directly connected to the output terminal of each (i.e., virtually no loading) then the linearity of the two circuits will not be significantly different.

The Anodic Oxidation of Aluminium

By G. C. Thompson

ALUMINIUM is generally regarded as a more or less incorrodible metal since a thin film of oxide forms on its surface, and it is well known that this prevents easy soldering of aluminium. This film, however, must be formed from the metal itself and therefore any accelerated formation will lead to corrosion of the underlying metal. The oxide coating is extremely thin and is not sufficient to prevent further corrosion of the metal in an atmosphere capable of attacking aluminium, e.g. a brine or strongly alkaline atmosphere. Thus with chlorine and alkalis the chemical reactions of aluminium are:—

$$2Al + 3Cl_2 = 2AlCl_3$$
$$2Al + 2NaOH + 2H_2O = 2NaAlO_2 + 3H_2$$

the metal forming aluminium chloride and sodium aluminate respectively. In combination with oxygen, the oxide is formed as shown:—

$$2Al + 3O_2 = Al_2O_3$$

Aluminium oxide is an extremely hard and unreactive substance in its natural state and occurs in various impure forms, among these emery, sapphire, ruby and corundum, the latter being second only to diamond on Moh's scale of hardness. Thus, early in the development of aluminium for industrial use—cheap aluminium, made by the electrolytic process, was unknown before 1868—it was realized that if the natural oxide film could be strengthened by any means, the metal would be much more resistant to corrosion. It should be noted, however, that natural aluminium oxide is in a fused state, whereas the coating formed on the metal is not. In this connexion also it is important to realize that the oxide is amphoteric, and will therefore dissolve in both acids and alkalis, particularly halogen acids. Despite this, it is a stable and unreactive substance.

Theory of Anodizing

It is easily seen that in order to supplement the existing oxide film some form of electrolytic process is ideal, but such processes are normally used for metallic deposition. However, by making the "work" the anode in an electrolytic cell, the negative ion group will attack it and if this ion group contains oxygen the formation of an oxide film is possible. Research on these lines led to the development of two main processes having basically similar principles but using different electrolytes and operating conditions. In one case a so-called "chromic acid" is used as electrolyte, while in the other sulphuric acid is used. Taking them in order, when chromium trioxide is dissolved in water a series of chromic acids is formed in accordance with the following equations:—

$$CrO_3 + H_2O = H_2CrO_4 \quad \text{Chromic acid}$$
$$2CrO_3 + H_2O = H_2Cr_2O_7 \quad \text{Dichromic acid}$$
$$3CrO_3 + H_2O = H_2Cr_3O_{10} \quad \text{Trichromic acid.}$$

True chromic acid is probably hypothetical, since there is doubt as to whether it has ever been isolated, so the solution may be said to be a mixture of the chromic acids.

Taking monochromic acid as typical of the series, in solution ions will be formed in the usual way

$$H_2CrO_4 = H_2^+ + CrO_4^-$$

The negative ion will, on electrolysis, attack the aluminium anode, thereby forming the oxide.

The reactions of sulphuric acid in electrolysis—here the sulphate ion goes to the anode—are too well known to need further comment.

The Chromic Acid Process (Bengough-Stuart Process)

The electrolyte used is a 3 per cent (by weight) solution of chromic acid, made by dissolving 4·8oz of chromium trioxide in each gallon of water required (i.e. 30gm per litre). It should be noted here that the substance having the chemical name chromium trioxide is commonly referred to in the trade as chromic acid and is usually purchased as such.

The article to be anodized is obviously made the anode in the vat, which is usually a steel tank, although any material which is resistant to chromic acid (e.g. glazed earthenware, porcelain, aluminium, etc.) can be used. If metallic, the vat is made the cathode, otherwise sheets of stainless or mild steel may be employed. The working temperature of the bath is preferably 100-108°F, but as no external source of heat is required to maintain this temperature the solution can be made up at about 110-115°F and then transferred to the vat. Filtration of the solution before use is recommended if it is seen to be at all cloudy, but otherwise it is not essential.

The work is wired up and cleaned as detailed in the General Notes, given a rinse in water and then placed in the vat. At the moment of switching on, the voltage should be between 5-10 volts, then raised 5 volts at a time to 40 volts in the first ten minutes, held there for twenty minutes, increased to 50 volts during the next five minutes and maintained at this level for the last five minutes, making time of treatment forty minutes. The solution should be stirred with a non-conducting rod from time to time to prevent polarization. During electrolysis, the current density should be 3A per sq. ft. for pure aluminium, 6A per sq. ft. for Dural type alloys and up to 20A per sq. ft. for high-silicon alloys.

After removal from the vat the article should be well rinsed in cold running water and dyeing must take place as soon as possible.

The Sulphuric Acid Process

Full details of this process are given by Wernick and Henley in British Patent Specification 476161, which is summarized here.

They show that as the applied voltage is increased during electrolysis, increasing current density is obtained up to about 18 volts, at which point formation of the coating breaks down. Also, for any applied voltage below this maximum there is a corresponding time of treatment beyond which efficiency of production and quality of coating fall off. This is due to the solution attacking the basic metal and the coating itself, forming what is probably a basic aluminium sulphate, which is non-adherent and powders when the film is dry. The ratio of rate of attack to rate of formation varies as time progresses and if the process is continued beyond the point required for maximum increase of weight although the actual thickness of the film may be greater, the quality of the coating is inferior. In the case of pure aluminium, the minimum temperature and strength of electrolyte are those which give an increase of weight of not less than 0·01gm per square decimetre in the first five minutes. The optimum strength of acid is that which corresponds to its maximum electrical conductivity, i.e. 15-22 per cent by volume, while the best voltage is between 12 and 13 volts. High temperatures lead to powdery coating and from 75-80°F is recommended, 85°F being the maximum. In carrying out anodization by the sulphuric acid process, the acid strength used industrially is about 36 per cent by weight, which is made by mixing 58·5oz of concentrated sulphuric acid with each gallon of water required. The acid is added to the water, very slowly, and with stirring. The mixing generates a fair amount of heat, and a vessel which is liable to crack should not be used. For this process, the vat employed must be one which is not attacked by strong sulphuric acid. A lead-lined vat is best, aluminium should not be used unless the acid is fairly dilute as it will gradually be attacked. Glass or earthenware are also quite suitable. As before, the "work" is cleaned and made the anode, the cathode being the vat itself (if metallic), or otherwise lead sheets can be fitted. The temperature of the solution should be approximately 70°F, which does not present any great difficulty. In the beginning, the voltage should be quite low (around 5 volts), then raised gradually to 12-13 volts, the total time of treatment being 30 minutes. The aforementioned Patent Specification gives a set of graphs showing the relationship between strength of acid, time of treatment, and increase of weight, which are very helpful for determining the duration of the process when varying acid strengths are used. From the point of view of the amateur, it is probably better to use a weak acid for a longer time, e.g. with 16·4 per cent by volume sulphuric acid about 45 minutes gives the greatest increase in weight. It must be remembered, however, that the time cannot be increased too much since the coating is then destroyed by the solution faster than it can be produced. For this process the current density should be 12A per sq. ft. for aluminium, 30A per sq. ft. for alloys and 15·20A per sq. ft. for Duralumin. The density of the electrolyte should be maintained between 1·225 and 1·200 by the addition of water or sulphuric acid as required.

Final Treatment

Having been anodized, the article is now ready for the final process, usually that of colouring the anodic film by means of dyes. There is, however, no real need for this dyeing process, since it is purely decorative and the main object of anodizing is protection from corrosion. If the article is not to be dyed, it should be thoroughly rinsed in cold running water to remove all traces of chemicals, then immersed in boiling water for a few minutes and allowed to dry. This treatment in boiling water seals the film, which is otherwise liable to staining at a later date.

Dyeing

Aluminium oxide, in common with the hydroxide $Al(OH)_3$ possesses the property of being able to absorb soluble dye particles, the hydroxide being used in the textile industry as a mordant, to render the dye "fast". A range of dyes made especially for use on aluminium is marketed by I.C.I. under the name "Alimax", and these give a very even colour. The author has found that dyeing may be carried out with domestic dyes, the "Tintex" variety, with a wide range of colours, being reasonably successful. In making up the dye-bath, it is essential that all the dye be thoroughly dissolved, as undissolved particles will cause darker patches or streaks. Filtering is probably the best method of ensuring that no solid particles or foreign matter remain in the solution. Some dyes work better if acetic acid is added in the ratio of 1:1000 (by weight), and according to Wernick and Henley (British Patent 474609) the acetic acid assists in the penetration of the dye and stabilizes the dye-liquor. A further refinement is the addition of a corrosion inhibitor to the dye-bath, which improves the corrosion resistance of the anodic film. Potassium dichromate, K_2CrO_7 (0·5 per cent by weight) is usually added, the process probably being analogous to the passivation of iron, cadmium, etc. Before using this inhibitor, however, a small test-piece of aluminium sheet or foil should be subjected to the entire process, as potassium dichromate reacts with some dyes. It must be realized that although the final shade of the colour chosen will depend on the strength of the dye solution, consistency

can only be maintained if the thickness of the anodic film is the same for all the articles. and those which are to be colour matched should have their anodizing conditions carefully controlled. This applies particularly in the case of front panels or chassis of units of electronic equipment which are to fit on a rack.

Wernick and Henley give 0·1 per cent by weight for the strength of the dye, but this may be varied as required, depending on the depth of colour wanted. The temperature of the dye-bath should be at least 180°F (but preferably at boiling point) and the article should be immersed for 15 to 25 minutes, the duration of immersion being almost directly proportional to the duration of electrolysis. It is claimed that by this method the anodic coating is not only tinted, but is also "sealed" against any further action, i.e. it is stainless and impervious to "leaching-out" by solvents.

At this point it must be emphasized that after removal from the anodizing vat the article must not be allowed to come into contact with grease or oil of any kind, nor must it be allowed to dry. Hot water must not be used for swilling either, as this will commence sealing the film before the dye has had a chance to "bite". After dyeing as above, the film is substantially sealed, but the dye is not necessarily light-fast and can be improved in this respect by immersion in a warm solution of a metallic salt, sometimes copper sulphate but more usually nickel acetate or sulphate. The strength of this solution is 2 per cent by weight, the time of treatment being 10 minutes. A further protection, used in the aircraft industry, is to treat with a solution of lanolin in naphtha.

Multichrome Dyeing

An article need not necessarily be dyed in one colour, as several colours can easily be produced on one film. The method is to dye the article first with the lightest colour used (e.g. yellow) then to bleach out with sodium hypochlorite solution (NaOCl) the parts which are not required to be yellow; the yellow area being protected by a clear cellulose lacquer. This process is then repeated progressing through the spectrum from yellow to indigo finally reaching black.

Removal of Films

If the film is patchy or streaky, a method is given of removing the film entirely. In this way a panel which might have been a total loss can be re-claimed.

The article to be stripped is placed for one minute in a boiling solution made up as follows:—

Chromic acid CrO_3, 3·4oz,

Ortho-phosphoric acid H_3PO_4, 7-8fl.oz (density 1·5),

Water, 1 gallon.

General Notes

A number of points which are common to both processes, and indeed to most electroplating, will now be dealt with.

Firstly, what is probably the most important step in the whole process is the chemical cleaning of the article to be anodized. Extra time spent on this will well be repaid later, as more films are spoilt by improper cleaning than in any other way. A fairly strong caustic soda solution can be used, but this has the disadvantage that it attacks the surface of the metal giving a matt finish. The usual polished surface can be preserved by using one of the organic grease solvents such as carbon tetrachloride, trichlorethylene, etc. (carbon tetrachloride is only dangerous when used on aluminium in a finely-divided state). Alternatively, a proprietary cleaner such as "Zonax" metal cleaner (used at 180°F-212°F) may be employed. The article can be tested for cleanliness by running clean cold water over the surface. Any tendency for the water to "tail" or form drops denotes the presence of grease. After cleaning, the article should not be allowed to come into contact with the hands or other greasy objects.

More care than usual must be exercised when wiring up articles for immersion in the vat, since the deposit formed is a good electrical insulator, and a loose connexion will rapidly become a highly resistant one, leading to inefficient working of the vat. Aluminium wire must be used for making all connexions which are to be immersed in the vat, as other metals are likely to go into solution and contaminate the electrolyte. For the same reason, any other metallic inserts which may be present in the article must be "stopped off" by means of a lacquer coating, since besides causing contamination, they will also draw a heavy and wasteful current. The electrolyte can usually be made up from tap water, as only in very rare cases is this unsuitable, the standard being that the chloride content shall not exceed the equivalent of 0·20gm of sodium chloride per litre.

Comparison between the two Processes

One is now faced with the question of deciding which process to use. Apart from certain fundamental properties of the methods which may make one more suitable than the other in a particular case, there is the availability of the materials and equipment to be considered. For example, a 3 per cent chromic acid solution is cheaper and easier to obtain than a 30 per cent sulphuric acid one, and is also less corrosive. A mild steel tank is probably easier obtained than a glass or lead-lined one. For those with a mains supply of 220V D.C. the chromic acid process has much to recommend it, since 50V is easily obtainable from it, and the current requirements are less than those required for the sulphuric acid process.

The chromic acid process is unsuitable for use with aluminium alloys containing more than 5 per cent copper, but the corrosion resistance of the film produced by it is better than that produced by the sulphuric acid process. Also, with the former process light gauge aluminium sheet may be bent without damaging the film, but this is not possible with the latter.

The greatest difference between the two methods lies in the appearance of the dyed film. With the sulphuric acid process, the metallic sheen is preserved and the finished product appears to be made of coloured aluminium whereas with the other process the surface is more matt and it is as though the colour had been laid on top of the aluminium surface. [This is due to the fact that the sulphuric acid oxide film is transparent, but the chromic acid one is not.]

Acknowledgment

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Radio Beacons for Lighthouses and Light Vessels

Twenty-watt duplicate radio beacons for lighthouses and light vessels at over forty locations on and around the coasts of Great Britain, Northern Ireland and the Republic of Eire have been ordered by Trinity House from Marconi's Wireless Telegraph Company Limited.

The new stations will represent the latest developments in the technique and design of medium frequency navigational radio beacons, providing fully automatic operation. The apparatus will be duplicated, with change-over switching, indicating, and alarm facilities, to prevent any stoppage of the service, and it will incorporate very high precision control arrangements to enable the stations to work to a rigid time schedule.

The new service which should be of immense assistance to shipping in these waters, particularly in foggy weather, is planned to come into operation on August 1, 1953.

A Simple Capacitance-Meter
Using a Crystal-Oscillator

By V. H. Attree,* B.Sc.

A 4Mc/s crystal-oscillator with a germanium rectifier and a milliammeter is used to detect small changes in a total capacitance of 200pF or less. Full-scale range is 1pF and changes of 0·01pF are easily detected. Power consumption of the single battery valve is only 120mW and initial drift, due to temperature effect, is negligible. Measurements may be made at full sensitivity within ten seconds of switching on.

THE capacitance-meter has come into wide use in recent years and commercial instruments are available both in this country and in the United States. A typical commercial capacitance-meter[1,2] has a full-scale range of about 1pF and is capable of detecting a change in capacitance of 0·01pF. For most laboratory purposes this range and sensitivity are adequate. Commercial instruments, however, are mains-driven and therefore require a warm-up period of from 10 to 30 minutes before readings can be made at full sensitivity. The duration of this initial warm-up period is a serious practical limitation as it means that the instrument cannot be used at short notice unless it is left permanently switched on. Temperature changes in the valves and components are the principal reason for the initial drift. It has been found that the difficulty may be overcome by using a low-consumption crystal-oscillator run from dry batteries; in the present instrument the required range and sensitivity are obtained with one miniature valve and a single tuned-circuit. The power consumption is 120mW, as compared with 20-60W, and the full sensitivity may be employed within 10 seconds of switching on.

A crystal-oscillator capacitance-meter consists of a valve with a quartz crystal between grid and cathode and a tuned circuit in the anode. The tuned circuit is so adjusted that, at the resonant frequency of the crystal, the anode impedance is slightly inductive. Under these conditions a very small change in capacitance at the anode causes a large change in the strength of the oscillation and also in the anode current. The arrangement was first described by Henriques,[3] who use it as a null-detector for the measurement of dielectric constant. A more recent paper by Alexander[4] describes an oscillator with a magic-eye tuning indicator to measure the anode current; this was also used for measurements of dielectric constant. Other applications have been by Lilley,[5] in a capacitance-manometer, and by Yousef and Sultan,[6] for vibration studies. The response of the crystal-oscillator to a change of capacitance is relatively slow, and there is little doubt that the dynamic capacitance-measurements of [5] and [6] are better made by other means.†

A paper by Neale[8] describes a two-valve arrangement consisting of a crystal-oscillator coupled to a reactance-valve. The reactance-valve avoids backlash by stabilizing the slope of the capacitance to anode-current characteristic at the resonant point; the sensitivity of the present circuit is approximately the same as in the reactance-valve arrangement, but backlash is avoided without the additional valve.

Circuit Description

The circuit diagram of the capacitance-meter is shown in Fig. 1. The working frequency is 4Mc/s which is high enough to enable small components to be used resulting in a compact assembly. The switch S_1 permits the anode circuit to be tuned either by the three parallel capacitors C_2, C_3 and C_4, or by an external variable capacitor. The strength of the oscillation is measured by the germanium rectifier D_1 and the 0-500μA meter M_1. Measuring the output with a separate rectifier, instead of depending on the change of anode-current in the valve, improves the stability of the output reading. The relation between rectified current and capacitance is shown in Fig. 2. The

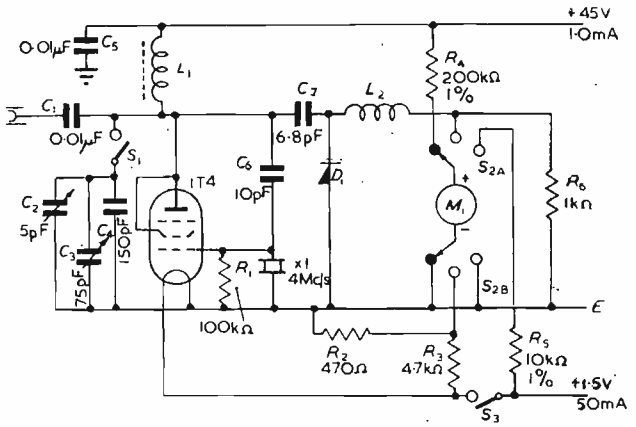

Fig. 1. Circuit diagram

current is measured in a resistor of 330Ω (equivalent to the working load) connected between the choke L_2 and earth. It will be seen that as the capacitance is increased the rectified current remains approximately constant until the point P is reached, then decreases very rapidly to Q where the oscillation ceases. The steepness of the characteristic between P and Q is determined by the total capacitance between the anode and the grid of the oscillator. In the present circuit this capacitance is made up of the 10pF capacitor C_6 and the anode-grid capacitance of the triode-connected 1T4, about 3pF. The capacitance increment from P to Q is 1·5pF; if C_6 is removed the increment becomes 0·5pF. In order to suppress the insensitive regions near the points P and Q (Fig. 2) the working range of the meter M_1 is restricted to the central portion of the characteristic. This is done by providing sufficient signal to give a maximum meter current of about 1·5 times full-scale and by injecting a delay voltage into the rectifier circuit. The equivalent resistance of the meter M_1 and the bias network R_2R_3 is 500Ω, so that a change in meter-current from zero to full-scale (500μA) gives an output of only 0·25V across the resistor R_6. If the capacitance-meter is required to drive another circuit, such as a counter or a servo-mechanism, this voltage is inconveniently small. A

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† *In the commercial version of the Lilley manometer the bridge circuit given by Tomkins[7] is used instead of the crystal-oscillator[6].*

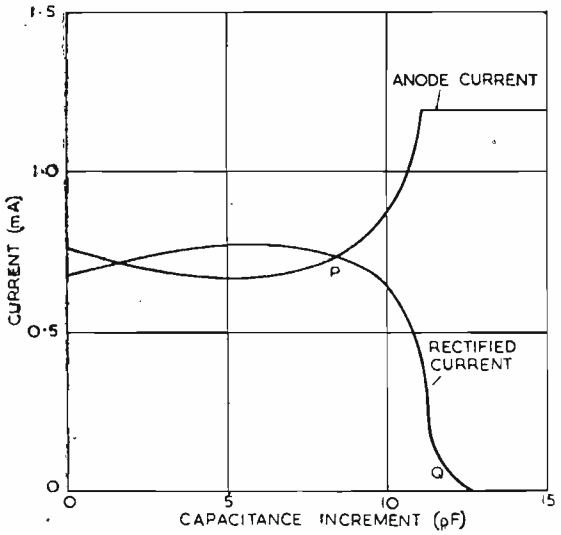


Fig. 2. Anode-current and rectifier-output plotted against capacitance

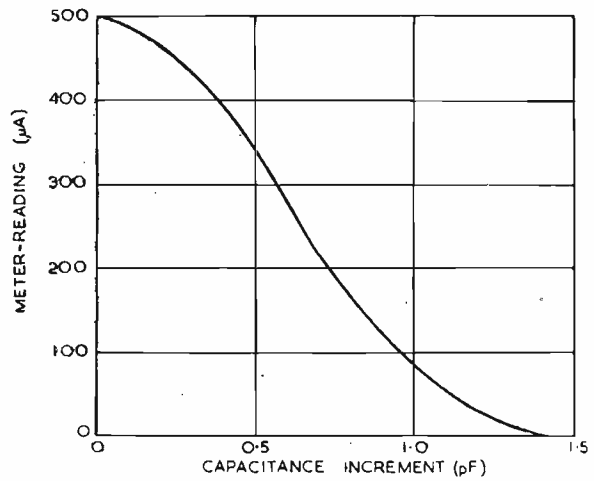
much larger output voltage may be obtained from a high-impedance rectifier circuit: for instance a germanium diode with a load of 100kΩ will give an output of about 10V.

The condition of the dry batteries may be checked rapidly by using the switch S_2. The filament is run from a single U2 dry cell and the H.T. from a 45V layer-type deaf-aid battery. The filament consumption is 50mA at 1.5V and the H.T. takes 1·0mA at 45V.

Calibration

The relation between capacitance and meter reading, Fig. 3, was measured with a precision capacitor. The calibration is nearly linear over the portion of the scale from 100 to 400μA. The sensitivity over this linear region is 0·018pF for 10μA, i.e. one division of the meter scale. Differences of one quarter of a division in the meter reading, representing 0·005pF, are detected and readings are repeated to within one half of a division, or 0·01pF. The instrument is normally used as a null-detector and the non-linearity at the two ends of the meter scale is not a disadvantage. If required, the linear range can be extended by correcting for the non-linearity with a non-linear element in the meter circuit: the non-linear element may consist of either a Metrosil disk or an additional germanium rectifier. The calibration depends to some extent on the characteristics of the rectifier D_1, and it has been found that, with a germanium rectifier, the amplitude and stability of the rectified output are much better than with silicon crystals, such as the 1N24.

Fig. 3. Relation between meter-reading and capacitance



Stability

As stated in the introduction, the drift of reading is small enough to permit accurate measurements to be made within 10 seconds of switching-on. Over the first hour the meter reading changes about 1 division, i.e. 0·02pF, and, provided batteries of reasonable capacity are used, the 24 hour drift is of the same order. Power consumption is only 120mW and temperature rise due to self-heating is negligible. The effect of changes in H.T. voltage, expressed as the equivalent change of capacitance, is as follows:—

H.T. Voltage	Capacitance (pF)
45·0	0·00
42·5	−0·05
40·0	−0·08

The temperature coefficient of layer-type deaf-aid batteries is about 0·1 per cent per °C. and a temperature change of 10°C. would be expected to alter the reading by somewhat less than 0·01pF.

The effect of filament-voltage change is as follows:—

Cell Voltage	Capacitance (pF)
1·4	0·00
1·3	−0·01
1·2	−0·02

It will be seen that the capacitance reading is affected much less by changes in the filament supply than by changes in the H.T. The effect of ambient temperature variations on the complete instrument is of roughly the same magnitude as the change due to the H.T. battery alone.

In some cases it is required to measure the change in a capacitance over a time-period of several hours (or days). This may be done by using a single-pole change-over switch to transfer the input of the capacitance-meter from the unknown capacitance to an auxiliary standard. The capacitance-meter is set to mid-scale with the unknown capacitance in circuit, and then the connexion is switched over to the standard which is adjusted until the meter again reads mid-scale. The meter batteries may then be switched off until the next measurement is required. The difference between successive settings of the auxiliary standard gives the change in the unknown capacitance over the test interval. The change-over is obtained by an ordinary toggle switch mounted in a screening box with coaxial connectors. For high accuracy the connecting coaxial cables should not be disturbed, and the whole set-up should be clamped to a solid table.

Frequency Response

The rapidity with which the circuit responds to a sudden change in capacitance is determined principally by the properties of the quartz crystal. The higher the crystal Q the slower is the *change* of total energy in the crystal circuit, and hence the slower is the response to a capacitance-change. The values of Q for some typical crystals are given by Pearson[9], for a 4Mc/s quartz-plate mounted in air the Q is about 50,000. The crystal used in the capacitance-meter is a quartz-plate with gold electrodes, mounted in an evacuated B7G envelope. The Q of this vacuum-mounted crystal is of the order of 100,000 and if we assume that the frequency response to a capacitance modulation is determined by the crystal alone, then the response will be 3db down for a modulation frequency of $f/2Q$ or 20c/s. The frequency response is measured with an air capacitor driven by a variable-speed motor. The stator consists of a single plate and the rotor is an eccentric disk; the capacitance modulation is approximately sinu-

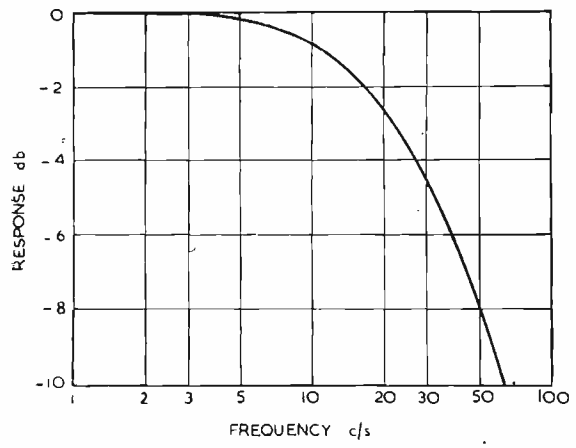


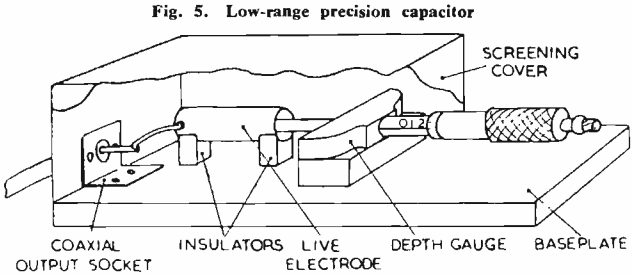
Fig. 4. Frequency response

soidal. The output from R_6 (Fig. 1) is amplified with a low-gain D.C. amplifier and measured on an oscilloscope. The frequency response is shown in Fig. 4, the output amplitude is 3db down at 22c/s and 6db down at 39c/s. An identical curve was obtained with a second crystal of the same type. Although it is not possible to improve significantly the frequency response by external damping, the use of an inferior (i.e. low Q) crystal will give a better response. With one particular wartime air-mounted crystal of the 10X type the response is 3db down at 240c/s. A low Q crystal may give a less stable instrument.

Low-range Precision Capacitor

When measuring very small capacitances it is convenient to have a low-range variable capacitor the calibration of which can be calculated. A range of about 1pF is required and if possible the calibration should be linear. A parallel-plate capacitor and many other configurations (e.g. a rod approaching a plane) are unsuitable because the capacitance cannot be expressed in terms of simple functions. One way out of the difficulty is to use two coaxial cylinders. The end of the inner cylinder is always well inside the outer cylinder so that the end-effect is constant. The capacitance law is linear and easily calculated. Capacitors of this type have been described by Wulf[10] and by Watson *et al.*[11] The design of these [10,11] consists of three main parts, a stepped rod at earth potential, a coaxial tube forming the live electrode and a coaxial outer screen. A much simpler design is shown in Fig. 5, a standard micrometer depth-gauge is used instead of a stepped rod and the outer screen is made larger. This reduces the minimum capacitance and simplifies the construction. The brass tube is 0·5in. I.D. and the depth-gauge probe is 0·1in. diameter. The capacitance law is 0·878pF per inch of travel; the depth gauge may be set with certainty to within 1 thou', hence, capacitance variations are accurate to 0·001pF. The effect of eccentric mounting of the central electrode is discussed in the appendix. An eccentricity as large as 0·01in. increases the capacitance by only 0·026 per cent so that

Fig. 5. Low-range precision capacitor



no great accuracy of alignment is needed. Coaxial capacitors have a relatively high minimum capacitance, but in view of the precision available, and the extreme ease of construction, it is perhaps surprising that they are not used more widely.

Conclusion

The main application of the instrument described is as a null-detector for measurement of capacitance in conjunction with a precision variable capacitor. The maximum capacitance that can be accommodated is about 200pF; this may be extended, with a proportional loss of sensitivity, by tapping down the coil. There are applications in both engineering and physiology, where the quantity to be measured changes slowly and here the crystal-oscillator circuit may be used with advantage. Because of the poor frequency response, however, the use of the circuit as a dynamic transducer is not always possible.

Appendix

The capacitance per unit length between two cylinders which are not exactly coaxial has been given by Jeffreys.[12] If α is the inner radius of the outer conductor, β the radius of the inner conductor and d the separation of the centres (i.e. the eccentricity):—

$$C = \frac{1}{2\cosh^{-1}\frac{\alpha^2+\beta^2-d^2}{2\alpha\beta}} \quad \ldots\ldots\ldots \quad (1)$$

Let the ratio of the radii $\alpha/\beta = K$ and $\alpha/d = N$, then:—

$$1/2C = \cosh^{-1}\tfrac{1}{2}\,[K + 1/K - K/N^2] \quad \ldots\ldots \quad (2)$$

If C_0 is the capacitance in the coaxial case and C_e the capacitance when the cylinders are eccentric; $K = 0.5$ in/0.1 in. $= 5$ and $d = 0.01$ in. (10 thou') giving $N = 50$ then:—

$$\frac{C_e}{C_0} = \frac{\cosh^{-1} 2.60}{\cosh^{-1}(2.60 - 0.001)} = 1.00026 \quad \ldots\ldots \quad (3)$$

i.e., with an eccentricity of 10 thou' the capacitance is only 0.026 per cent greater than when the cylinders are perfectly co-axial.

The direct numerical solution used above is probably the simplest approach and has the advantage that it does not include the assumption that d is small. However if we start with this assumption then, for the particular case of $\alpha = 0.5$ in. $\beta = 0.1$ in., it can be shown that:—

$$C_e/C_0 = 1 + 2.6d^2 \qquad \text{(where } d \text{ is in inches)}$$

which gives the same result as (3).

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Millimicrosecond Pulse Techniques

(Part 2)

A High Speed Oscillograph

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

Part 1 of this article described a number of basic circuits which are applied to complete instruments in these Parts and in Part 4.

The material is arranged to demonstrate practical application problems, to extend the ideas of Part 1, and to introduce further techniques.

Part 2 outlines the oscillographic equipment used to view fast waveforms, and details of the more specialized circuits are given. Part 3 is then devoted to a description of apparatus for expanding millimicrosecond pulse intervals on an analogue principle, and examples of application to laboratory measurements are suggested in the conclusion.

FOR the study of the fast phenomena which are the subject of these articles, ordinary oscillographs must be supplemented by an instrument of greater resolution. This section outlines one of the high speed oscillographs used by the authors, which has proved versatile and is equally suitable for repetitive work, or nuclear investigations where the signals arise randomly in time. Since recent literature[1,2] describes several high speed oscillographs, detailed discussion may be restricted to the more novel design features.

An American Du Mont 5XP11 C.R.T., operated with 2 and 10kV pre- and post-deflexion accelerations, gives sufficient brilliance for the observation and photography of single transients on the fastest sweep speed of 1mm/mμsec, and a resolution better than 10^{-9}sec is available in the absence of Y plate amplification.† The time-base has durations of 0·1, 0·3, 1, 3, and 10μS and fires 5-10mμsec after receipt of the triggering pulse. The firing level is adjustable and may be set between 0·2 and 25V as measured at the input to the time-base trigger valve.

The amplifier system divides into three parts: an output push-pull C.R.T. deflexion unit having a gain of 30 and bandwidth from 100kc/s to 150Mc/s; a time-base trigger amplifier with a gain of 10 which may be coupled into the output system; and low level amplifiers which can be added to raise the overall gain to 10,000 with a reduction in bandwidth to about 100Mc/s. All inter-amplifier connexions use 200 ohm coaxial plugs, sockets and cable, which affords great flexibility in the amplifier arrangements.

As here described the output and trigger amplifier are shown operated from a common signal, with a delay inserted in the signal channel. This is the arrangement employed for the observation of a random pulse which itself trips the time-base. Alternatively the trigger and output amplifiers can be separated, and each may be preceded by low level amplifiers.

Fig. 1 shows a block diagram of the output and trigger amplifiers according to the former arrangement. The trigger amplifier consists of eight 6AK5 valves connected as a distributed amplifier[3,4,5] of approximately 200Mc/s bandwidth, with 200 ohm grid and anode lines. The input pulse travels along this unit's grid line and proceeds directly into the 100ft length of 200 ohm concentric cable, while the anode line of the trigger amplifier feeds the time-base trigger circuit which is described below. After the 0.1 μsec†† delay produced in this way, the signal pulse travels along the grid line of the paraphase amplifier and then into the grid line of one of the pair of output amplifiers, while the other output amplifier has its grid line driven from the anode line of the paraphase unit. The latter

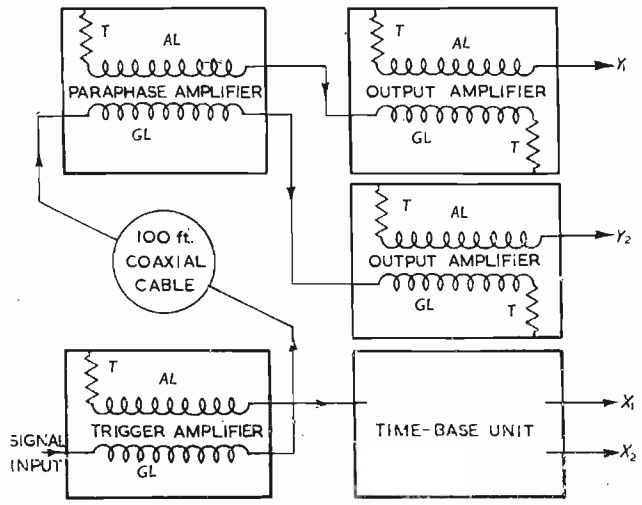


Fig. 1. Block diagram of oscilloscope
GL—grid line, AL—anode line, T—line termination

consists of two 6AK5's, used as a distributed amplifier, working into a 200 ohm anode line and therefore having a gain of unity.

Each output distributed amplifier contains fourteen 6AK5's, with 200 ohm grid line and 250 ohm anode line. Each amplifier output feeds the corresponding Y plate through a small inductance arranged to form a half-section of the correct impedance in conjunction with the Y plate capacitance. Both output amplifiers, and the paraphase unit, can be biased asymmetrically to allow for maximum current change for either polarity of input pulse. With

* *Ministry of Supply, England*
** *National Research Council, Canada.*
† *The English G.E.C. tube type* 1608 *gives somewhat similar performance.*

†† *Various lengths of delay cable are used according to the time-base length. The value quoted would centralize the waveform on a* 0.2μsec *scan.*

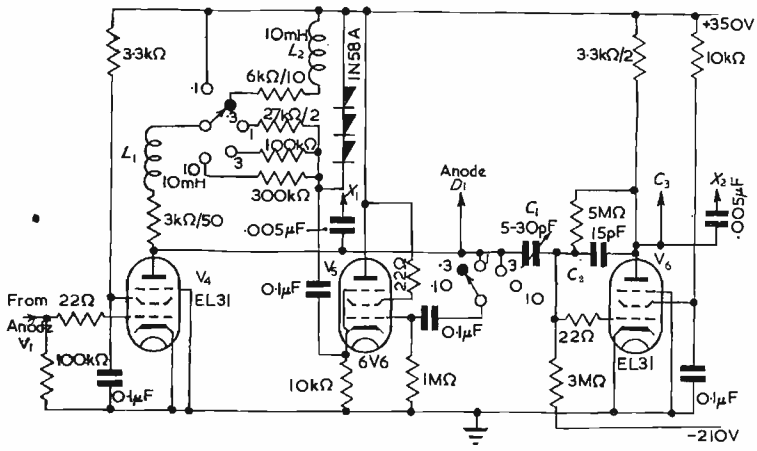


Fig. 2. Time-base circuit

15mA swing from each valve, a combined output of 100 volts is available, giving 1·25in. possible vertical deflexion. By omitting a resistive termination at the output end of the anode line the output voltage is doubled, and the resultant reflected pulses are absorbed in the resistive termination at the reverse end of the line. For an input rising in less than 1mμsec, the output system gives a rise time of about 3mμsec.

The low level amplifiers are conveniently arranged in self-contained units with individual power supplies, each consisting of two stages of six 6AK5's and giving an overall gain of 10 at a bandwidth of 170-200Mc/s. Little space need be devoted to them here. While they prove simple to construct and align, the authors have found it more economical to use the commercial units manufactured by Hewlett Packard or Spencer Kennedy of the U.S.A. These are modified on receipt by replacing their non-matching connectors by the 200 ohm type.

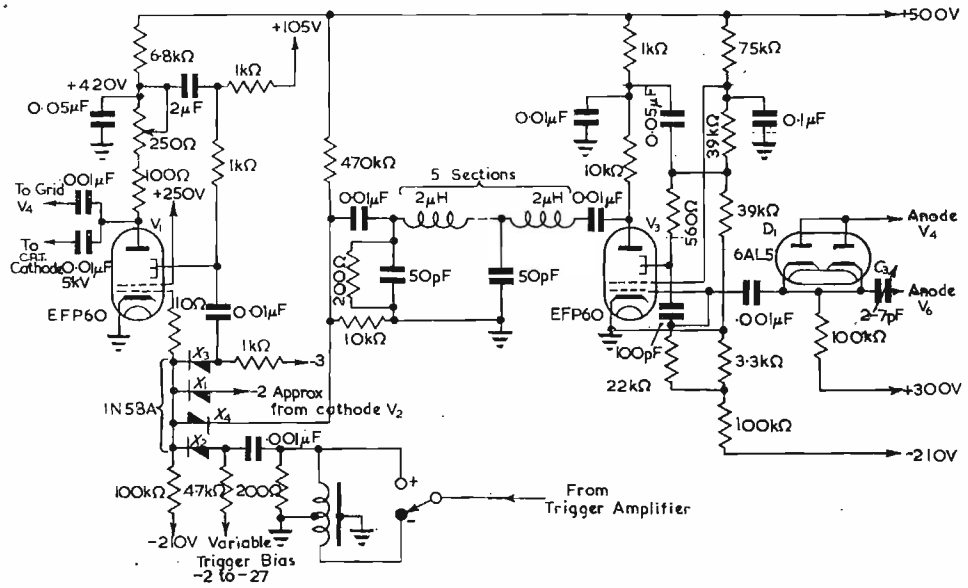
In the time base-unit, the required 250 volt paraphase time-base waveforms are generated by V_4 and V_6 (see Fig. 2). V_4 is normally conducting, with an anode current determined by the switched anode load, while V_6 is held at about 15mA anode current by the D.C. negative feedback network from anode to grid and the negative line. When V_4 is cut off by a negative square-wave applied to its grid, its anode rises at a rate determined by the anode load and the total anode capacitance, the latter including the deflector plate X_1 of the C.R.T. At the same time C_1 and C_2 act as a floating paraphase system compelling the anode of V_6 to fall at the same rate as the rise on V_4, with the adjustment of C_1 enabling equality to be obtained in spite of the finite gain of V_6 and the stray capacitance loading on its grid. By maintaining a constant charging current, the chokes L_1 and L_2 linearize the two shortest sweeps, while the same function is carried out by the cathode-follower V_5 on the longer time-base ranges.

The negative square wave applied to the grid of V_4 also modulates the cathode of the C.R.T. to provide the "brighten-up" waveform. Its amplitude is therefore made variable over the range 30-80V. This waveform is generated by the time-base trigger circuit, Fig. 3, where V_1 is the sensitive high speed trigger circuit described in Part 1 of this series. For clarity the D.C. negative feedback stabilizing system is omitted in Fig. 3, including the cathode-follower V_2 which supplies the control potential to the cathode of diode X_1. The coupling capacitor from dynode to grid of V_1 is so chosen that this circuit, alone, would generate a waveform of duration about 20μsec—appreciably longer than the longest time-base. (Observation of the anode waveform of the EFP60 trigger circuit shows that its natural period must be long compared to the time-base duration if the "brighten-up" waveform is to have a reasonably flat top.) However V_3 is employed in a second trigger circuit which is tripped by the time-base waveform at the end of the time-base sweep and is used to terminate the "brighten-up" waveform from V_1.

Since V_3 is not required to trigger on a small signal, its stability can be ensured merely by biasing it beyond cut-off, as in the heavy duty trigger circuit described in Part 1. When the time-base waveform on the anode of V_4 (Fig. 2) has risen to 300 volts, diode D_1 conducts, giving at its cathode a pulse which triggers V_3. Capacitor C_3 is adjusted to equal the cross capacitance of D_1 and so cancels the capacitive break-through which would otherwise occur. The triggering of V_3 drives the cathode of the diode X_4 negative, and so causes the anode of V_1 to rise. In addition to ending the "brighten-up" waveform this also reverses the time-base sweep, the anode of V_4 then falling. If this occurs before V_3 has been fully triggered there is a possibility that its anode will now rise, consequently permitting V_1 to re-trigger and giving a form of multivibrator action between V_1 and V_3, with V_4 and D_1 acting as coupling elements. This is avoided by the inclusion of a 5 section network giving a total delay of 50mμsec, which ensures that V_3 has time to be irreversibly triggered before the time-base fly-back occurs.

One useful ancillary should be mentioned in conclusion. It is often impossible to load the circuit under observation with the 200 ohm impedance demanded by the amplifiers. This limitation has been overcome by development

Fig. 3. Time-base trigger circuit
V_5 and associated stabilizing networks omitted



of a small probe unit whose input loading approximates 2pF. It consists essentially of a single 6AK5 having as its anode load the 200 ohm amplifier input cable, and whose grid is coupled to the probe signal terminal via an aperiodic divider network. The signal passes from the terminal via 1pF, shunted by 100kΩ, to the grid; where voltage division takes place due to the input capacitance of the valve, adjusted to 9pF, and shunted by 11kΩ.

There is a voltage loss of 10 when using the probe, which will handle input signals up to 10V. In order to extend this range a nosepiece may be fitted to the probe which, since it contains a similar attenuator cascaded on the first, increases the loss to 100 times and so allows signals up to 100V to be observed without overloading the 6AK5.

The probe unit is in the form of a small cylindrical can fitted with a polythene nose on which the signal spike is mounted. By its use the waveforms of high speed circuits may be inspected with the ease associated with conventional low bandwidth oscillography.

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(Part 3)

Time Expansion for Millimicrosecond Pulse Intervals

By N. F. Moody,* A.M.I.E.E.

THE apparatus to be described is an analogue time convertor: its output pulse is a precise multiple of the input time interval. An input time may be defined in terms of a pulse duration, or with greater freedom by two pulses whose leading edges define the interval. It is the latter method which has been adopted here.

When time expansion is performed on intervals in the microsecond scale the problem is a simple exercise in conventional circuit techniques. It will, nevertheless, be useful to outline such a scheme which can be made the basis of a much faster circuit (see Figs. 1 and 2).

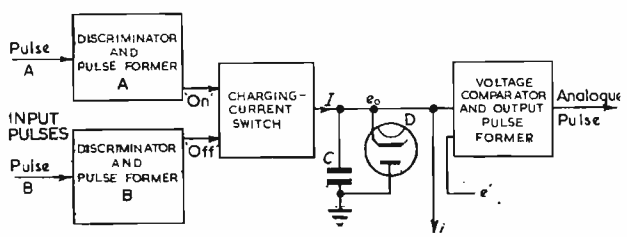


Fig. 1. Block diagram of analogue time expander

Pulse A is to define the commencement of the timing period, to be terminated on the arrival of pulse B. These signals are applied to two discriminators, whose function is to trigger at precise amplitudes e_a and e_b on the respective input wavefronts, and to generate therefrom two square waves whose front edges are separated by the time interval $(t_b - t_a)$ which is to be expanded. These waveforms, which are to control the charging current switch, must be maintained for a time greater than the total expansion. Prior to the arrival of pulse A a current-i is supplied to the integrating capacitor C, but since the latter is by-passed by the diode D the upper plate is held at a potential which differs from earth only by the small constant e_o, to be neglected in the first instance. When discriminator A fires, the additional current I is applied and a voltage V develops across C such that:

$$V = 1/C \int_{t_a}^{t_b} (I - i)\, dt$$

* *Ministry of Supply, England.*

At time t_b when the second discriminator operates, its output waveform overrides that of discriminator A and the current I is switched off. There is then a decay of V towards ground under the influence of $-i$, and the initial conditions are restored when:

$$\int_{t_a}^{t_b} (I - i)\, dt - \int_{0}^{T''} i \, . \, dt = 0$$

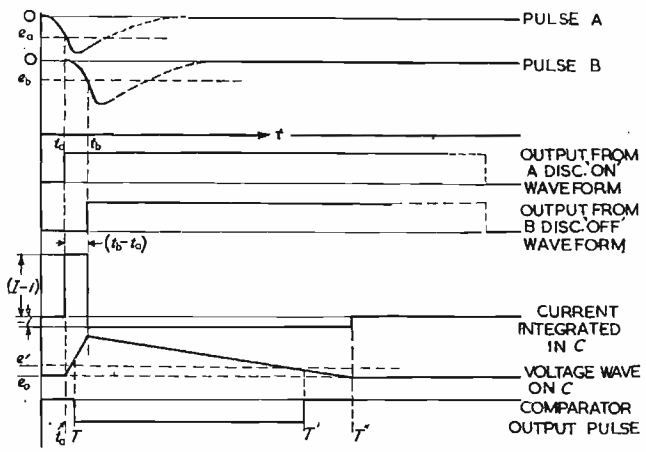


Fig. 2. Waveforms of microsecond analogue time expander

The voltage comparator is, ideally, a device which detects the departure of V from ground (or more precisely e_o) and at this instant generates the leading edge of a square wave to be completed when V again returns to its starting level. In practice a finite voltage will be required to actuate the comparator, whose threshold then becomes a constant e'. When the currents are assumed to be linear with time and the constants are neglected, recognizing that the output pulse duration is $(T'' - t_a)$, the time expansion ratio n is given by I/i. Inclusion of the constants e_o and e' causes it to be modified to

$$n' = I/i \left(1 - \frac{e' - e_o}{V}\right) \quad \ldots\ldots\ldots\ldots \quad (1)$$

corresponding with the interval T to T' shown in Fig. 2.

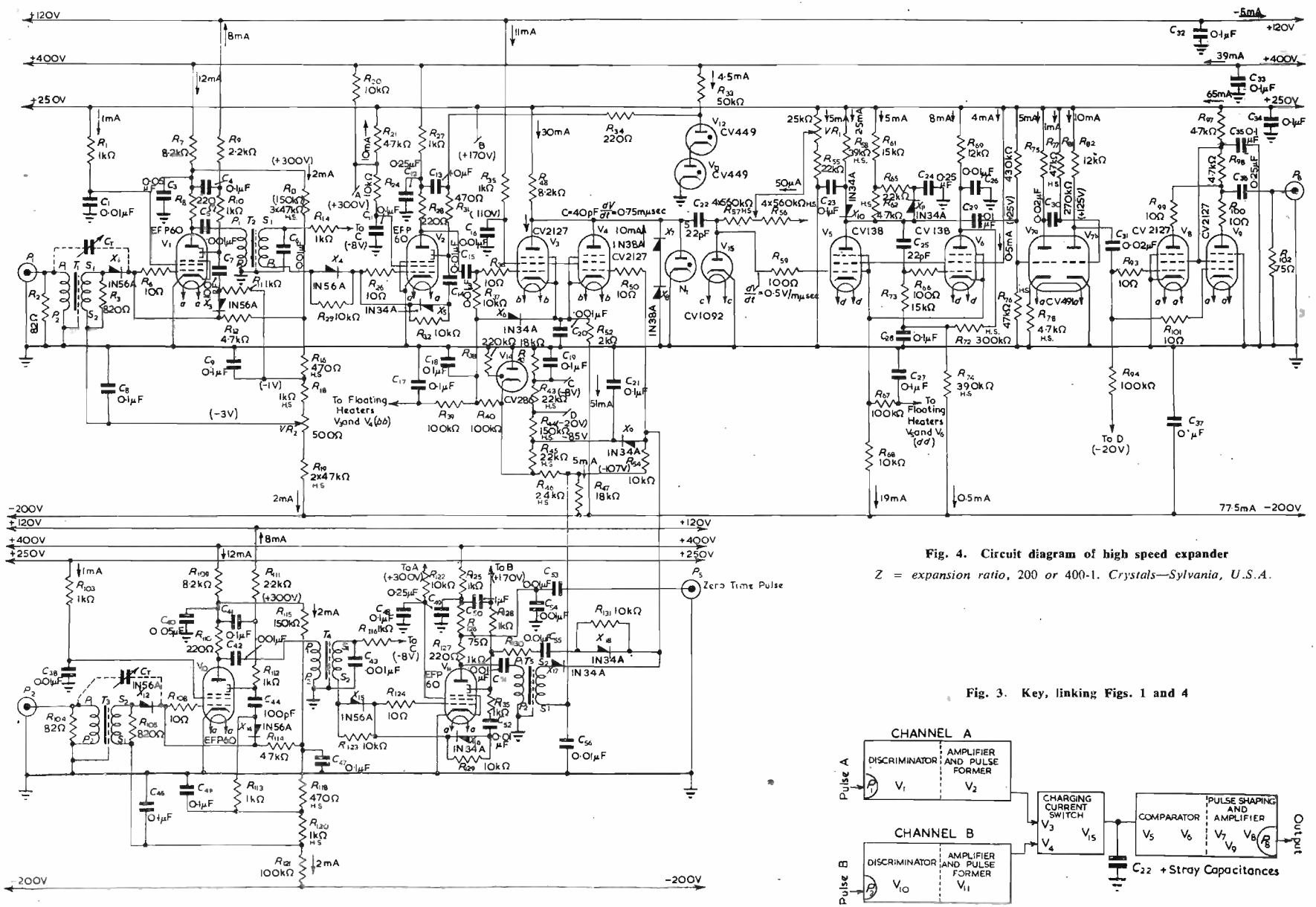


Fig. 4. Circuit diagram of high speed expander

Z = expansion ratio, 200 or 400-1. Crystals—Sylvania, U.S.A.

Fig. 3. Key, linking Figs. 1 and 4

Problems of the High Speed Expander

In the high speed expander, now to be described, the range of input time intervals is 10-100mμsec, the expansion ratio 400, and the desired accuracy $\pm$ 2 per cent or 0·5mμsec whichever is the greater. When an attempt is made to apply the principles described to this ultra-short time scale it is found that certain key factors dominate the design. It will be helpful to state them before proceeding to circuit details.

The discriminators must maintain the accuracy of their firing levels on steep wavefronts in order that the timing interval may be properly defined, and furthermore the delays in the systems A and B preceding the charging current switch must be constant to 0·2mμsec. This demands that the transmission delay in each of these channels shall itself be small.

The charging current switch must set up the heavy current I to 1 per cent and its intermediate states between "on" and "off" conditions must be traversed in times less than 1mμsec if indeterminacy from this source is to be minimized.

It is well known that a major source of errors in sawtooth timing systems is due to variability in the constants e_0 and e', and the fractional error so caused is indicated by the last member in Equation (1). With practical values of charging current the sawtooth amplitude V falls below 10V at the shortest intervals. Great emphasis is therefore placed on maintaining these constants precise, and a special trigger circuit has been developed for use in the comparator.

Circuit Description of the High Speed Expander

A complete circuit diagram of the instrument is shown in Fig. 4, the function of which will be most easily followed in conjunction with Fig. 3. The latter links the block diagram of Fig. 1 with Fig. 4 by showing the valves employed in each part of the operation.

At this stage the detectors (which generate the input pulses from the phenomenon under investigation) may be neglected and it will be sufficient to specify test signals applied to P_1 and P_2. Both waveforms are identical except for their relative time delays, are negative and increase their amplitudes threefold in 2·5, 5, or 10mμsec centred around the triggering threshold of two volts.

Each channel is identical except in its coupling to the charging current switch, and only channel A will need complete description. The waveforms of the system are shown in Figs. 5 and 6.

The 75 ohm coaxial cable bearing the detector signal A is terminated at the transformer T_1 where it is also phase inverted and the voltage is stepped up 1·5 times at the secondary. The transformers, which will receive separate discussion, do not introduce more than 1mμsec delay.

Comparison of the circuit of V_1 with that of the sensitive EFP60 trigger circuit described in Part I will show that they are identical in principle. A simplification exists in the D.C. feedback arrangement, R_7, R_{13}, R_{16}, R_{18}, VR_2, R_{19}, which omits the cathode-follower. This is permissible since the repetition rate is less than 50c/s so that quick recovery is not required. Crystal X_3 interrupts the dynode loop and is biased to -1V, and crystal X_1 which forms the discriminator is biased to -3V.

The crystal capacitance of X_1, which would allow direct break through of signal, is cancelled by the small trimmer C_T ($\approx$ 1pF) taken to the antiphase signal existing at the primary of T_1, and the channel sensitivities are then equalized by adjustment of VR_2. When these settings are correctly made the trigger circuits are insensitive to input wavefront rate over the test range quoted and the difference between channel firing levels may be held within 0·07V at a nominal firing level of 2V. This represents a possible error of 0·2mμsec at the mid test rate.

The output of V_1 fires the heavy duty trigger circuit V_2, also described in Part I, via the unity ratio phase inverting transformer T_2. For this purpose the relaxation time of V_1 need not exceed a few microseconds, and this allows the capacitors of this critical circuit to be held at values of reasonably low self inductance. V_1 is used as a sensibly constant current source of 100mA which charges the strays of the coupling circuit to the grid of V_2 and fires the latter. The crystal X_5 is important in this

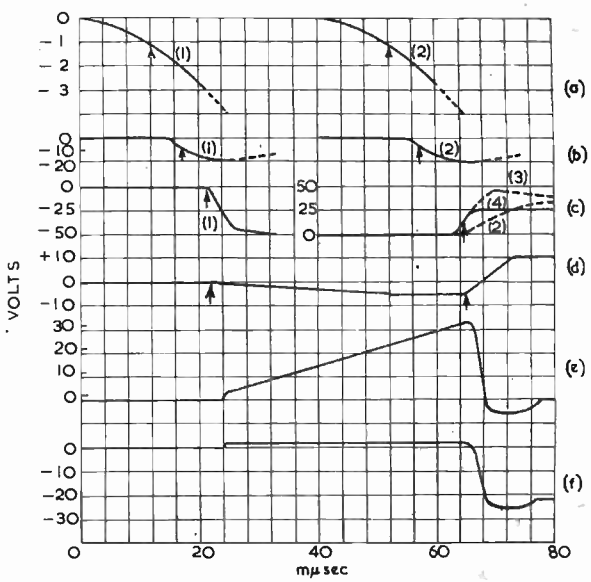


Fig. 5. Fast waveforms of the high speed expander

(*a*) Waveforms applied to P_1 and P_2 from test gear. Delay 40mμsec. (1) To channel A. (2) To channel B.
(*b*) *Anode waveforms of discriminators.
(*c*) *Switch actuating waveforms.
(1) Anode V_8 (2) Non-limited signal from V_{11} dynode
(3) Non-limited signal from T_5 secondary (4) Mixed limited signal as supplied to switch.
(*d*) *Cathode motion V_3-V_4.
(*e*) Charging waveform, anode V_3-V_4.
(*f*) Waveform V_{18} grid.
**Waveforms so marked neglect a* D.C. *voltage constant on the ordinate.*
† *Denotes actuating point of the subsequent circuit.*

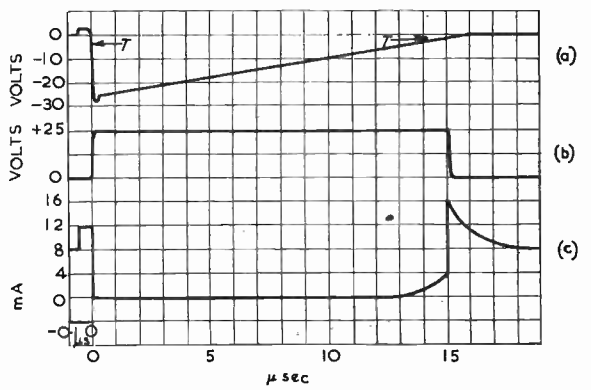


Fig. 6. Slow waveforms of high speed expander

(*a*) Expanded sawtooth at V_5 grid with triggering thresholds marked T.
(*b*) Anode waveform V_5.
(*c*) Anode current V_5.
Note change of scale to left of origin.

role, since it isolates the low dynode load of V_2 from the grid circuit drive, and thereby not only reduces delay in firing but renders this delay much less susceptible to the forward impedance of X_4. This latter crystal in turn allows the reflexing action of V_2 to be isolated from V_1 so that the early recovery of the latter does not disturb the 50μsec switching waveform produced by V_2. Since V_2 is

cut off in the quiescent state, it can turn on the heavier current (250mA) required to produce a rapid switching action into the capacitance of V_6. The first 12V of the anode switching wave of 50V delivered by V_2 is employed for this purpose and the action is completed some 6-10mμsec, after the input pulse from the detector has reached triggering threshold. Since each transformer introduces about 1mμsec delay, and each EFP60 is calculated to have a transit time of some 2mμsec, this overall delay approaches the theoretical limit and is largely controlled by factors which are not subject to variation.

It will be shown that a negative switching wave is necessary to close the charging current switch, and a positive wave of similar characteristics to open it again. Hence the switching waveform in channel B, from V_{11}, must be phase inverted. Since it is not possible to design a transformer to phase invert the 100μsec anode wave and yet deliver the required fast wavefront, the " body " of the switching wave is taken from the dynode of V_{11}. The smaller dynode currents do not allow such fast transients as the anode, and furthermore such loading of the dynode reduces the efficiency of the reflexing circuit. The switching waveform applied to V_4 grid is therefore synthesized from two components: a fast edge decaying exponentially in 0·1μsec taken from the anode of V_{11} through T_5, and the slower body of the waveform taken from the dynode via R_{130}. These are added via the crystals X_{17} and X_{18}. A resistor R_{135} inserted in the dynode loop causes its initial positive jump to become greater and ensures that the waveform amplitude is limited by the crystal X_9 to 25V. At the high values of current involved in the various circuits, crystal forward resistances are significant. Thus although the crystal bias is set to limit at 22V the waveform actually reaches 25V amplitude. Similar remarks apply to crystal X_6 mentioned later. Capacitor C_{55} is so chosen that the subsequent slow dynode voltage rise (see heavy duty trigger circuit waveforms Part I), causes current to flow in X_9 throughout the switching waveform, so that the latter has a flat top as is required by the switch circuit.

The charging current switch uses the principle of diverting the charging current into any of three routes, one of which is the integrating capacitor. This is done without requiring the current to produce any appreciable voltage at the switching-on discontinuity (which would involve charging time delays). The author is not aware of any other technique which will allow a precise current to attain a final value in times whose order is 1mμsec.

In the quiescent state the anode of V_3 absorbs the charging current of 30mA which flows via R_{48} and which is therefore near ground potential. The cathode of V_3 is at -93V so that the cathode current is 50mA, and this gives rise to excess anode current which is absorbed by the crystal diodes X_7 and X_8. Thus the anode potential is clamped at this lower limit (-2V) and the charging current is known precisely in terms of the stabilized line voltage, crystal forward voltage, and R_{48}. Since the crystal current is also defined this drop will be constant and a precision of $\frac{1}{8}$ per cent might be a reasonable estimate of the charging current stability for perfectly stable line voltages.

When trigger circuit V_2 fires, V_3 is shut off. The cathode by-pass capacitor C_{20} holds the cathode stationary at this instant, but afterwards it gradually falls until, if the input interval is long enough, it is clamped by crystal X_6 which thereafter defines the cathode potential and absorbs the 50mA flowing in R_{52}. V_4 remains non-conducting since its grid is still biased some 12V below its cathode. The current which had been flowing in V_3, i.e. 30 mA, now flows into C_{22} and the stray capacitances, where it is integrated.

Returning for a moment to the action of V_3, the system of diverting the current by switching off a grid was taken as an essential feature of any design adopted. No limit need thereby be placed on the general regularity of the switching waveform apart from the steepness of its edge; and it was felt, furthermore, that whatever stray cathode inductances might exist in the switched valve, sufficient amplitude of switch impulse would assuredly stop the current with no more delay than the valve transit time.

The total capacitance of the anode circuit V_3 and V_4 is 40pF, which includes C_{22} whose lower end is grounded through diode V_{15}. At the commencement of integration C_{22} possessed charge only by virtue of the voltage drop across X_7 and X_8 (-2V) and the "contact" potential of V_{15} which was then carrying a current of 50μA due to R_{56} and R_{57} (or 100μA if R_{57} was in circuit alone). The latter potential will be close to zero, and the net charge corresponds with part of the constant e_0 (see Fig. 2). At the instant of switching C_{22} commences to charge, and the increase of current in V_{15} causes a small rapid rise of about 2V which is in opposition to the component of e_0 already described. Thereafter C_{22} charges at 0·75V/mμsec and the rate is sensibly constant since the resistor R_{48} is chosen to have a sufficient inductive component to linearize the sawtooth. Crystals X_7 and X_8 are chosen so that at the maximum stress, -75V, their reverse current does not exceed 1 per cent of the charging current (i.e. 0·3mA), and the neon lamp N_1 serves to protect them from excessive surges which would impair their back resistance.

On the arrival of Pulse B, V_{11} triggers, raising the grid and cathode of V_4 and so taking the current from X_6. The sawtooth on the anodes V_3, V_4 then collapses rapidly so causing the anode of V_{15} to be driven negatively, via C_{22}, by a value proportionate to the charge received. The subsequent discharge of C_{22} by the small current in R_{57}, R_{56} (50-100μA) then gives the required time expansion. The method of sawtooth formation described, which differs in detail from that treated in the introduction, divides the waveform into two parts; the fast charging wave terminated by an abrupt recovery to zero, all of which requires high currents and relatively low insulation and whose circuit elements lie to the left of the integrating capacitor C_{22}; and the complementary discharge portion which involves low currents and high insulation and is isolated from the switch system by C_{22}. Only the leakage of C_{22}, the anode insulation of diode V_{15} and the grid insulation of V_5 can give rise to erroneous discharge currents.

The switch valve V_4 is hence called upon to fulfil the following requirements. Firstly it must terminate the charging action in a time short compared to the measured interval (i.e. dV/dt must be reduced to zero). Secondly it must return the anodes V_3 and V_4, and so the plate of C_{22} to the quiescent potential in a time very short compared to the expanded output. These requirements are met, for capacitor C_{20} is so chosen that the demanded rise at the cathode of V_4 will transfer an adequate charge to the anode circuit to discharge the stray capacitances completely in a few millimicroseconds. In practice an excess charge is transferred which is absorbed by X_7 and X_8, so that there is a slight overshoot. This decays, in the same order of time, leaving V_4 drawing a steady current (since its grid is clamped against X_9) which is 5 per cent in excess of that originally drawn by V_3. This small, but defined increase, is absorbed by X_7 and X_8. The slight difference in voltage drop results in a further slight modification to the constant e_0.

The division of charge between C_{22} and the stray capacitances of V_{15} and V_5 results in some 30 per cent amplitude loss, so that seen at V_5 grid the sawtooth has a peak value of 0·5V for every 1mμsec of input interval. Thus the voltage comparator must be constant to 0·1V for a 0·2mμsec stability. In order to achieve this performance it has been necessary to devise a trigger circuit which is unaffected by contact potential (which may easily vary by 0·25V). The circuit to be described relies on the constancy of the ratio of anode current to mutual conductance in a valve; which, at a suitable point on the characteristic, is substantially controlled only by the valve geometry and

may therefore be expected to remain constant throughout life, and indeed to be little affected by valve changes.

Valves V_5 and V_6 form a univibrator (a trigger circuit with one stable and one semi-stable state) in which each valve draws equal current in the quiescent state. This is achieved by D.C. negative feedback. Thus V_5 grid is taken to V_{15} anode, sensibly at ground potential, and the cathodes of V_5, V_6 are taken via R_{68} to -200V, so setting up a current of 19mA. This current is forced to divide equally by negative feedback taken from the anode of V_6 (bearing a load R_{69}) via the network R_{72}, R_{74} feeding its grid. In this way each anode is made to draw 8mA, and this current, on which the triggering threshold depends, is not appreciably influenced by the D.C. potential of V_5 grid due to contact potential changes in V_{15}, or at the grids of V_5 and V_6. The ratio of anode/screen current in each valve, another geometrical factor, enters as a small variable in the balance of current, but its influence is negligible.

V_5 anode is cross connected to V_6 grid by C_{25} in the conventional manner, so forming an anode-grid, cathode coupled, univibrator which would be unstable were it not for crystal X_{10}. This crystal acts as a shunt to V_5 anode load and reduces the loop again far below unity in the quiescent state. The anode current of V_5 is made to divide into 2·5mA flowing via R_{58} and X_{10}, and 5·5mA flowing in R_{61} and R_{62}. It follows that the grid of V_5 must be depressed $2{\cdot}5\text{mA}/g_m'$ before X_{10} ceases to act as a shunt and this value $\approx 0{\cdot}7$V is defined in terms of the ratio of slope to anode current. (g_m' is the mutual conductance of V_5 as a triode, whose cathode works into a load which is the reciprocal of V_6 mutual conductance (also treated as a triode). It is approximately $0{\cdot}6g_m$, where g_m is the anode mutual conductance.)

The negative sawtooth applied to the grid of V_5 causes this valve to cut off and the anode rises according to the usual exponential law, as determined by the anode stray capacitances, until crystal X_{11} limits it after about 25V. This crystal receives its bias from the resistor R_{65} taken to the anode load tapping and decoupled by C_{24}. Thus only a short segment of the anode exponential is employed and the rise time lies between 10^{-7} and 5×10^{-8} sec. It is important to notice that at this point of clamping the loop gain once more falls abruptly at a grid depression on V_5, corresponding with:

$$\frac{2{\cdot}5\text{mA}}{g_m'} + 25\text{V}/14\text{K} \;.\; 1/g_m' \approx 4{\cdot}3/g_m' \approx 1{\cdot}2\text{V}$$

where the first term has already been explained and the second term is the further change in the resistive component of anode current required to clamp on X_{11}. This is the constant e' (Fig. 2). We neglect the cathode feedback which takes place in this calculation for reasons to be explained. Taking an expanded pulse of 50mμsec $\times$ 400 $= 20\mu$sec it will be seen that the coupling time-constant to V_6 grid $\approx 0{\cdot}4\mu$sec will allow the grid of V_6 to return to its initial bias within the expanded interval, but since V_5 grid is still held negatively by the sawtooth the whole of the 19mA set by R_{68} remains in V_6.

As the sawtooth decays the current in V_6 gradually diminishes and is restored in V_5. However, the system will not retrigger until X_{11} unclamps at the grid voltage defined above, where both the valves are again on their working characteristics. Thus the retriggering threshold is again defined by the ratio of anode current to mutual conductance.

When the system retriggers the grid of V_6 will be driven 25V negatively so that all current will be transferred instantaneously to V_5, but the currents equalize again in the next few microseconds as V_6 grid returns to its quiescent potential. The remainder of the circuit can be dismissed with little comment. The expanded wave is taken from V_5 anode, for it is only at this anode that a simple square wave is available, to the phase reverser V_{7a} which has a relatively small input capacitance. The output of this triode then feeds V_{7b} which sharpens the input pulse and drives the output valve grids from cut-off at -20V into grid current. These output stages deliver some 300mA into a 75ohm terminated cable so producing a negative square wave of 10-12V amplitude whose edges rise and fall in about $0{\cdot}1\mu$sec. A typical calibration curve for the complete instrument, set to an expansion ratio ≈ 300 is given in Fig. 7.

For the sake of completeness brief mention will be made of the terminal apparatus driven from the expander. The output wave from the expander is applied to a second low speed expander where the duration is increased yet a further thousandfold, making an overall expansion of 400,000, or 0·4 millisecond per millimicro-second input interval. This allows results to be recorded on a slow medium such as magnetic tape.

A requirement of the apparatus is that it shall record a single datum only during its expansion interval, and this is necessary in certain experiments where the detectors may give rise to spurious signals subsequently to the observation. To eliminate this danger a "lock" system is incorporated in the second expander (where the slower pulses make the design easier). It operates within 1μsec of the termination of input (once expanded) pulse and since the first expander is itself dead for 300μsec after an observation the whole system is paralysed for a time duration for

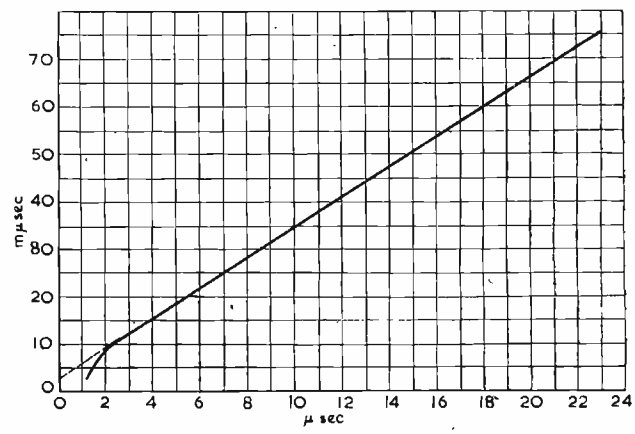


Fig. 7. Typical calibration of high speed expander. Expansion ratio $\approx$ 300

0·1sec. This dead time also obliterates signals which the first expander generates as its trigger circuits V_{11}, V_{12} relax. (The dead time is arbitrary and relates only to the particular measurement for which the design was produced. Its lower limit need be little more than the overall expansion time).

Measurements Involving the Expander (used without terminal equipment)

No doubt many laboratory applications of the time expansion principle will occur to the reader. The following, which are chosen to avoid security aspects, exemplify the methods which may be employed. It should be pointed out that not all of these experiments have been performed at the time of writing.

Using the test pulse generator as a signal source the expander may be used to measure or equalize cable delays. If the trailing edge of the expanded pulse is viewed on a delayed fast time-base a time difference of 0·1mμsec is easily observable.* The accuracy when studying such small differences is greatly improved by heating valves V_5, V_6 and V_{15} with D.C. to eliminate 50c/s ripple.

Extension of the scheme to the measurement of valve transit times or circuit delays is straightforward. In a linear system the greatest accuracy will result when the

** In some of these experiments additional constant delay must be added in one channel so as to bring the delay difference within the range of the expander.*

delayed and undelayed pulses are of equal amplitude for then the input circuits to the channels of the expander are identical.

An application where amplitudes would not be equal is the plotting of a waveform whose rise time or repetition rate is such that oscillographic viewing is difficult. For this purpose the first channel would be fired from any convenient time reference and the sensitivity of the second channel adjusted, a range of 0-25V being suggested, so as to sample the rise time to various fractions of the peak level.

It is found that photomultipliers of the 27.M.1 class, whose electrodes are biased to suitable values, make excellent detectors where light transients are involved. Any dynode may be used as a collector, so that gains from unity to 10^5 are available in steps of 4 (the dynode multiplication ratio) without increasing normal transit times. Pulse currents in excess of 100mA can be obtained before saturation occurs, whatever electrode is employed as the collector, so that signals up to 7·5V in amplitude are available in a terminated 75 ohm cable and this is a suitable level for operation of the expander.

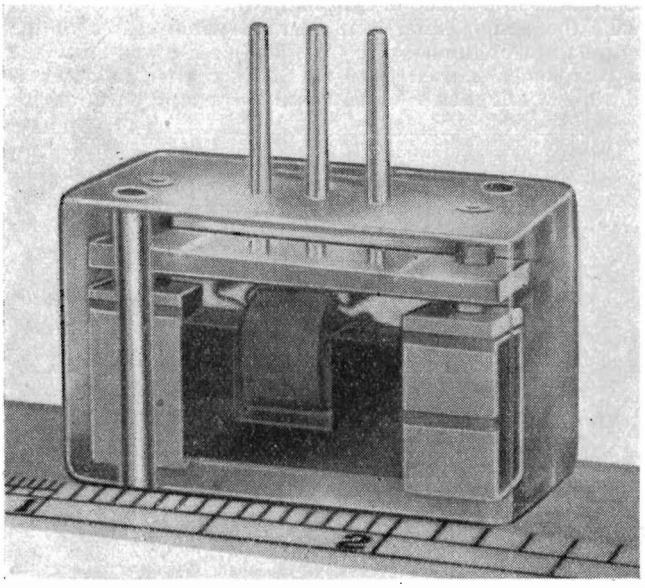


Fig. 8. The construction of the emblocked pulse transformer

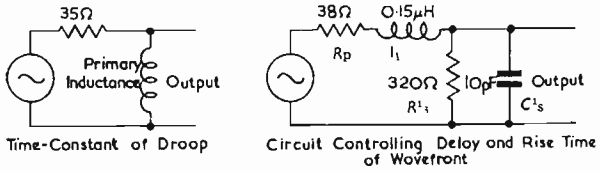


Fig. 9. Equivalent unity ratio circuits of input pulse transformer

Photomultiplier detectors have been used to study the build up of light following rapid electronic discharge in gases. Again, photomultiplier transit times and dispersions form a promising study which may be aided by expansion techniques. In this latter experiment, following work by J. Sharpe of A.E.R.E. Harwell, it is proposed to generate a pulse of X-rays by means of a small 20kV X-ray tube whose emission may be controlled by bias of some 60V applied to a grid. When the grid is modulated from cut-off to full beam current by means of a relay pulse generator (see Part 1) a pulse of X-rays will be generated whose edges should be in the order of 1mμsec. If the beam then impinges on an organic phosphor (e.g. stilbene) the delay time and dispersion of the photomultiplier can be calculated. Alternatively, within the limitations of the photomultiplier constants, the decay times of phosphors lying in the millimicrosecond range could probably be measured by this method.

Part 4 of this article will be devoted to the study of short nuclear half lives by methods which do not involve time expansion principles. Present techniques depend on measurement of the time difference between the pulses from two photomultipliers fitted with organic phosphors which respectively detect the primary and secondary nuclear radiations which define the half life under study. The problem differs from those treated in this section, inasmuch as the pulse pairs occur randomly in time, but the expansion system promises to be very useful when suitably developed for this purpose.

Appendix

Design of the Pulse Transformers

The transformers are wound on Ferroxcube III, and the core is formed from two blocks 5mm x 5mm x 27mm slotted and placed in contact as seen in Fig. 8. The contacting surfaces are ground.

Below is given data common to both input and intervalve transformers except where indicated.

Slot size: 6mm long x 0·5mm deep, in each block.

Core insulation: 0·5mm paper.

Primary: 5 turns 34 s.w.g. enamel covered wire, close wound.

Insulation: 0·5mm paper.

Electrostatic shield: 0·1mm copper foil, grounded both ends to the core clamps.

Insulation: 0·5mm paper.

Secondary: (input transformer) 8 turns 34 s.w.g. enamel covered wire close wound.

Secondary: (intervalve transformer) 5 turns 34 s.w.g. enamel covered wire close wound.

Approximate electrical constants of the input transformer are:—(See equivalent circuits of Fig. 9).

Primary inductance (calculated)	= 35μH
Low frequency time-constant (measured)	= 0·8μsec
Primary capacitance (calculated)	= 0·9pF†
Secondary capacitance of winding (calculated)	= 0·6pF†
Circuit capacitance loading secondary	= 3pF
Total secondary capacitance referred to primary (C'_s)	= 10pF
Leakage inductance referred to primary (calculated) (l_1)	= 0·15μH
Damping factor $*\sigma = \left(R_p/2l_1 + \frac{1}{2R'_sC'_s}\right)\sqrt{\frac{l_1C'_s}{1 + R_p/R'_s}}$	= 0·33
Delay time to 50 per cent final value (calculated)	= 1mμsec
Rise time to step function input,	
10 per cent-90 per cent (calculated)	= 1·4mμsec
Measured rise	≈ 1mμsec

†*Lead and terminal capacitance increases this, perhaps 0.5pF.*

*σ = 1 *is critical damping,* F = 0 *is undamped.*

(To be continued)

Letters to the Editor

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

Distributed Amplification

DEAR SIR,—In his article on the Distributed Amplifier in the April issue Mr. Cormack mentions the use of mutual inductance between sections of the transmission lines. Briefly the advantages of employing mutual inductance are these:

(1) For a given cut-off frequency the characteristic impedance of a line, and hence the gain of a stage, is increased by a factor m; m being related to the coefficient of coupling (k) between coils by the expression, $m = \sqrt{\frac{1+k}{1-k}}$.

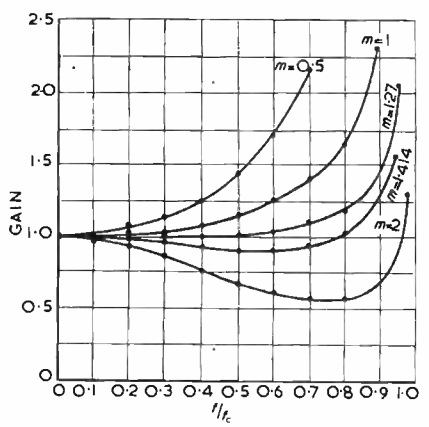
(2) If m is greater than unity there is a more linear phase shift through the pass-band, the optimum value of m being 1·27.

The method of coil construction, i.e. an open continuous helix, shown in Mr. Cormack's article will not give sufficient coupling between coils for the value of $m = 1{\cdot}27$ to be obtained.

There are practical difficulties in designing coils with the correct amount of mutual inductance between sections. Expressions for the mutual inductance between sections of a continuously wound single layer solenoid show that the mutual inductance is dependent on diameter, number of turns and length of winding; unfortunately the self-inductance of the individual sections is also dependent on exactly the same variables, therefore obtaining the correct values of both quantities is apt to be rather tedious. It is sometimes found that even with a close wound helix a fine gauge of wire has to be used, and this has mechanical and electrical disadvantages.

An alternative method of construction is to wind each half section of an inductance element in a close spiral, the coil being sandwiched between sheets of perspex or polystyrene for rigidity. Each half section is free to move along an insulated rod and the distance between it and its neighbour is adjusted to give the correct mutual inductance, without in any way affecting the self-inductance. Details of coils of this type used in an amplifier with 120Mc/s pass-band for a line of 400 ohms impedance are as follows: number of turns (half section) 6·3 (0·46μH), inner diameter $\frac{1}{4}$in., wire 26 S.W.G., and approximate distance between radial planes of adjacent coils $\frac{1}{8}$in.

Fig. 1



An expression for the self inductance of spiral coils is given by Wheeler,[2] this formula gives satisfactory results for the type of coil employed.

The main disadvantages of the latter form of construction are the increased complexity of manufacture and an increase in the stray capacitance across a section.

Yours faithfully,

R. W. A. SCARR,

Electrical Engineering Dept.,
Queen Mary College,
London, E.1.

REFERENCES

1. KALLMAN. *Proc. I.R.E. 34*, 646 (1946).
2. WHEELER. *Proc. I.R.E. 16*, 1398 (1928).

The author replies:

DEAR SIR,—I agree with Mr. Scarr over the two advantages that are obtained by employing mutual inductance between sections of the transmission lines. I would add the further advantage that the frequency response curve may be made more nearly linear by employing the correct amount of mutual inductance. Ginzton, Hewlett, Jasberg and Noe[3] derive an expression for the gain and time delay of an amplifier with this type of line:

$$\text{Gain/section} = \frac{g_m R_0}{2} \cdot \frac{1}{[1-(1-m^2)x_m^2]\sqrt{(1-x_m^2)}}$$

and

$$\text{Delay/section} = \frac{2}{\omega_c} \cdot \frac{m}{[1-(1-m^2)x_m^2]\sqrt{(1-x_m^2)}}$$

where R_0 = low frequency characteristic impedance of line

$$x_m = \frac{\pi f R_0 C}{m}$$

C = actual capacitance/section of line.

It will be observed that the equations for gain and time delay are of similar form. I have plotted curves for various values of "m" in normalized form (Fig. 1) and it appears to me that a value of "m" somewhat greater than 1·27, say 1·4, would be an advantage. It should be appreciated that the value quoted for "m" by Mr. Scarr is obtained by considering the transmission properties of an "m"-derived filter when a signal is applied across the complete shunt arm, whilst in its present use the signal is applied across the capacitor in the shunt arm of the filter (Fig. 2).

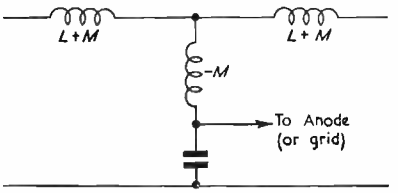


Fig. 2

I must disagree with Mr. Scarr's statement that an open continuous helix will not give sufficient coupling between coils for the value of $m = 1{\cdot}27$ to be obtained. May I refer him back to his reference.[1] Here, Kallmann states that a simple way of adjusting "m" is to correctly proportion the length and diameter of an open helix. This may be derived as follows:

Consider a helix radius = a and length = b

Let it be wound with X turns/inch and be tapped at the centre.

By Wheeler's Formula[2]

$$\text{Total inductance } L_T = \frac{a^2X^2b^2}{9a + 10b}$$

Inductance of half the helix

$$L_H = \frac{a^2X^2(b/2)^2}{9a + 10(b/2)}$$

The mutual inductance between the two halves

$$M = \tfrac{1}{2}[L_T - 2L_H]$$

$$= \frac{a^2X^2b^2}{2}\left[\frac{1}{9a+10b} - \frac{1}{18a+10b}\right]$$

By definition the coefficient of coupling

$$k = M/L_H$$

$$= \frac{a^2X^2b^2}{2}\left[\frac{1}{9a+10b} - \frac{1}{18a+10b}\right]\frac{4(9a+5b)}{a^2X^2b^2}$$

$$= \frac{9a}{9a+10b}$$

Thus k is independent of X and is determined only by a and b.

For $m = 1{\cdot}27$ $\quad b/a = 2{\cdot}94$

This is the value of b/a used in the construction of the helices described in my paper.

The correct value of "m" was arrived at by experiment. Presumably, if the cut-off frequency is lowered to, say, 120Mc/s, where valve input impedance damping is considerably less, a higher value of "m" might be an advantage.

Yours faithfully,

A. CORMACK,

The Research Laboratories,
The General Electric Co. Ltd.
Wembley, Middx.

REFERENCES

1. KALLMAN. *Proc. I.R.E. 34*, 646 (1946).
2. WHEELER. *Proc. I.R.E. 16*, 1398 (1928).
3. GINZTON, HEWLETT, JASBERG and NOE. *Proc. I.R.E. 36*, 956 (1948).

BOOK REVIEWS

Application of the Electronic Valve in Radio Receivers and Amplifiers Volume II

By B. G. Dammers, J. Haantjes, J. Otte and H. Van Suchtelen. 431 pp. 343 figures. Philips Technical Library, Holland, and Cleaver Hume Press Ltd., London. December, 1951. Price 45s.

SO much has already been written on audio frequency amplification that a new book on this subject, especially one covering 425 pages, needs either to present the material in a much simpler manner or else to include a great deal that is new. While the treatment is orthodox, orderly and comprehensive, this book contains nothing which would make the designer feel that it is an outstanding contribution to knowledge. It bears the stamp of translation and there is much circumlocution; this, together with unfamiliar symbols and sometimes wrongly termed phenomena, makes it an unwise choice for the student.

There are three chapters dealing with audio frequency amplification, (83 pages) the output stage (280 pages) and power supply (100 pages). The first chapter starts with a brief discussion of *RC*, choke and transformer coupling and then transfers attention to phase-splitting circuits for push-pull operation. The authors very wisely draw attention to the dangers of trying to derive the 180° phase shift from the output circuit itself. A return is made in the next section to the coupling circuit, and its effect on frequency response is considered as well as those of the cathode, anode and screen circuits. Preference is given to a series of generalized curves covering the audio frequency range rather than the single curve to which they may often be reduced. The term "linear distortion" is used rather curiously to describe what is commonly known as attenuation distortion. The design, with an example, of an A.F. transformer and valve distortion are covered in the last two sections. The reference on page 62 to NK being proportional to frequency is confusing and should be omitted.

The next chapter which is the longest, would have been greatly improved by a severe pruning and less might have been devoted to theoretical analyses which could better have been summarized. Class A, AB and B stages are considered and are well illustrated with reference to Philips valves. The use of n as the primary/secondary turns ratio of the output transformer on page 87 may prove confusing when compared with Fig. 40 (page 54) where the opposite convention is employed. The optimum load of a Class A valve is not determined by whether it is used in a single or push-pull connexion. The load seen by the valve across the half primary is, however, affected by any other valve taking current and connected to the same transformer. The authors do not make this point sufficiently clear on page 112. The last sections of this chapter deal with intermodulation, harmonic distortion and its calculation, the construction of complex load locus curves, and the calculation of output power and operating conditions. The bibliography at the end of this chapter mainly refers to Dutch and German publications, but it is nevertheless surprising that no mention is made of B. J. Thompson's pioneer work on Class B load lines.

The third and last chapter is divided into four sections comprising filament supply, rectifying circuits, their design calculations and H.T. stabilizer circuits. In the first section problems of series operation and current stabilization of heater supplies are considered, and this is followed by a general discussion on rectifying circuits (vibrators as well as valves) in the next section. The function of the reservoir capacitor is presented in a confused manner on pages 352/353; what should be stressed is that for a fixed load mean and peak currents are increased by adding the reservoir capacitor though the duration of the current pulse is reduced. Theoretical curves of D.C./peak voltage ratio for different angles of current flow and different ratios of internal to load resistance for single and polyphase circuits are given in Section 3. Calculation of R.M.S. current taken from the transformer leads to the salient design features of the mains transformer. A useful table of procedure for design calculations rounds off this part. No elaborate stabilizing circuits are dealt with in the final section, which concerns itself only with gas-filled stabilizers.

K. R. STURLEY

Transmitting Valves

By J. P. Heyboer and P. Zijlstra. 284 pages + xii, 19 tables. 256 figures. Philips Technical Library, Holland, and Cleaver Hume Press Ltd., London. December 1951. Price 35s.

THIS book, based on the Dutch edition published in 1946, has been brought up to date by P. Zijlstra and fills a long-felt need for an authoritative treatment on the subject of transmiting valves suitable for the advanced student and professional engineer. It is written in a lucid style which immediately inspires confidence. Rigorous proofs are incorporated and the results of these are applied to practical examples. The many diagrams and figures are an admirable feature of the book.

Chapter I deals with the technology of transmitting valves and includes details of tungsten and carburized thoriated tungsten filaments, oxide-coated cathodes and the materials and constructions available for anodes, grids and envelopes.

Chapter II contains a brief classification of valves according to number of electrodes, power handling ability and function.

Chapter III is concerned with the triode as an R.F. power amplifier and is subdivided into two main parts. In the first, the arguments for class A, B and C conditions are based upon the assumption that I_a is unaffected by changes in V_a and that the I_a/V_g characteristics have constant slope, the effects of curvature being investigated later. In the second section calculations are made for linear I_a/V_a characteristics of finite slope terminating in the "limiting characteristic" for the class C condition. The maximum output powers are determined with due reference to the anode dissipation, steady anode current and peak current limitations and these results are conveniently summarized. Some further items of special interest are included, e.g., grid current and driving power, detuning of the anode circuit and over excitation. On page 71 it is erroneously stated that the output power is at a maximum when the anode circuit is detuned. That this is not intended may be inferred from the context.

Chapter IV is concerned with tetrodes and pentodes as R.F. amplifiers and includes discussions on the effects of the screen grid and secondary emission, so leading to the beam tetrode and pentode. The advantages of tetrodes and pentodes over triodes are summarized at the end of the chapter.

Chapter V deals very fully with amplitude modulation of R.F. amplifiers and control grid, screen grid and suppressor grid modulation are followed by anode modulation. "Modulation characteristics" are derived and the effects of modulation upon efficiency deduced, first for a pentode having ideal characteristics and any requisite modifications are then deduced by reference to practical characteristics. Limitations set by permissible screen dissipation are included and justification is given for the statement that there is no difference in principle between triode and pentode anode modulation. The conditions for satisfactory amplification of amplitude modulated signals are next considered, the need for class B operation being shown and the resultant effect upon efficiency deduced. Finally, combined modulation methods, e.g., anode and screen grid modulation, etc., and modulation powers required for the various modulation methods are included.

Chapter VI—"The Transmitting Valve as Oscillator"—opens with a discussion of the principal circuits used, namely the Hartley, Colpitts, and Tuned Anode-Tuned Grid. The establishment of the equilibrium condition, the stabilization of oscillation amplitude and the determination of both amplitude and frequency of oscillation are all given interesting treatment. The applications of transmitting valves in R.F. furnaces, dielectric heating, diathermy and the generation of supersonic oscillations conclude the chapter.

Chapter VII deals adequately with frequency multiplication.

Chapter VIII is entitled "Some Special Items." Under "Grid Emission" thermal and secondary emission from control and suppressor grids are discussed together with the application of secondary emission in producing a negative resistance component in order to reduce the required excitation power. On page 179 reference is made to "a sinusoidal pulsating voltage" and this is shown diagrammatically as a series of peaky pulses; it is difficult to appreciate why the term "sinusoidal" has been used. The arguments used to deduce almost self-evident results on pages 179 and 180 from

an oscillogram photograph in which negative resistance due to secondary emission is exhibited seems somewhat cumbersome and not in keeping with the remainder of the book. Discharges in transmitting valves are included, and reference is made to the possible damage which may result from them and the circuitry and constructional safeguards which may be employed to avoid damage to the filament assembly. Polyphase filament connexions are then considered as a means of reduction of hum generated by A.C. heated filaments. In Chapter III no account was taken of the effects of losses occurring in the amplifier load. These effects are fully considered in this chapter and the requisite modifications to the performance figures are obtained. Finally, a method is described for the measurement of the static characteristics of transmitting valves at positive grid potentials.

Chapter IX gives a very lucid outline of the development of Lecher wire and coaxial line oscillators, for frequencies up to 200Mc/s, from the conventional lumped impedance Hartley and Colpitts circuits. The effects of valve capacitances and lead inductances are considered and the failure of the conventional neutralization of triodes at high frequencies is explained. A range of high frequency valves, including triodes, tetrodes and pentodes, is described. The author has explained in his preface that he intends to publish a separate work on valves and their operation at frequencies involving transit time effects.

The Appendix contains much useful information on a proof of Simpson's Law for the evaluation of areas subtended by curves. A.F. class A and class B power amplifiers and the use of constant current characteristics.

The work concludes with a summary of technical data relating to Philips transmitting valves and transmitter rectifiers.

Although errors do occur many are purely typographical and few materially detract from the usefulness of this commendable book.

L. G. DIVE

Laboratory Instruments—Their Design and Application

By A. Elliot, Ph.D., D.Sc., and J. Home Dickson. M.Sc. 414 pp. Chapman and Hall, Ltd. December, 1951. Price 32s.

THIS book contains a wealth of information of practical value in designing new equipment and should be generally useful to all engaged on instrument construction. It is based on the wide experience of the authors accumulated during many years of applied research, and the application of the principles laid down should result in instruments which will work successfully with the minimum of elaboration. No attempt has been made to cover the whole field, and the main emphasis is on mechanical construction and optical instruments.

The first few chapters deal with the properties and treatment of various materials, the preparation of drawings for workshop use, and the capabilities of workshop machines. There is a detailed discussion of the kinematic design of instruments which contains many excellent examples of simple and effective pieces of equipment constructed on these principles. Chapters on vibration-insulation, sensitivity and methods of measurement follow. The importance of optical instruments in nearly all research calls for special attention and much information of a type not normally included in books on optics occupies the remaining space of this book. Included among the descriptions of various types of optical equipment are the modified Schmidt projection systems which are being used for the projection of television pictures. Mention is also made of stereoscopic projection, and there is a section on photography.

A series of appendices contain details for the computation of a corrector plate for a Schmidt camera, data on the optical constants of some natural and synthetic crystals, notes on ray tracing and conversion tables for different systems of angular measure. A valuable feature of the book is the large number of references given to authoritative works on the various ramifications of the subjects treated.

W. C. PRICE

Elektromaschinen, Band II (Electrical Machines, Volume II)

By Kurt Seidl. XIII +184 pp. 186 illustrations. Franz Deuticke, Vienna. 1951. Price £1 10s. 10d.

THE first volume of this treatise was reviewed in the November 1951 issue of this journal. The second volume is devoted to synchronous machines, D.C. machines, A.C. commutator machines, and cascades for A.C. and D.C. Throughout special attention is given to the dynamics of electrical machines in accordance with its great importance. Construction, mode of action, the way by which static characteristics are arrived at, and how by suitable dimensioning the working of the machines may be influenced, are discussed and useful hints are given to the student for their design. Due consideration is given to more recent developments. So for instance there is a special account of D.C. machines with intermediate brushes, e.g., the crossfield generator and its derivatives, the metadynes and amplidynes, and their dynamics is dealt with in an appendix. As regards their historical development described on pp. 98-100 some slight errors might be corrected in a second edition of the book. The crossfield generator was developed by Rosenberg in 1904, first for train lighting and slightly afterwards as a welding generator. The patent for Deri's crossfield convertor was applied for in 1906 after Rosenberg's pioneer patent and description had been published in 1906 and 1905 respectively. That the development of Elin's welding generator was not finished before 1928 was due to the peculiar patent situation. In a brief bibliography at the end of the book only continental books are mentioned. The spelling of the name Vidmar should be corrected in a second edition. But these are minor blemishes, probably due to the loss of the author's collection of material during the war. They do not impair in any way the value of this thought-stimulating treatise which, as has been stated before, is at the same time comprehensive and concise and, on the whole, may be considered as a valuable addition to the literature of electrical machines.

R. NEUMANN

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ELECTRONIC EQUIPMENT

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

Hanovia Mercury Vapour Detector

(Illustrated below)

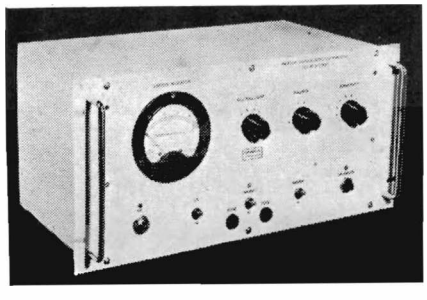
THE Hanovia mercury vapour detector has been developed to indicate the amount of mercury vapour in an enclosed atmosphere, either continuously or at intervals, as required.

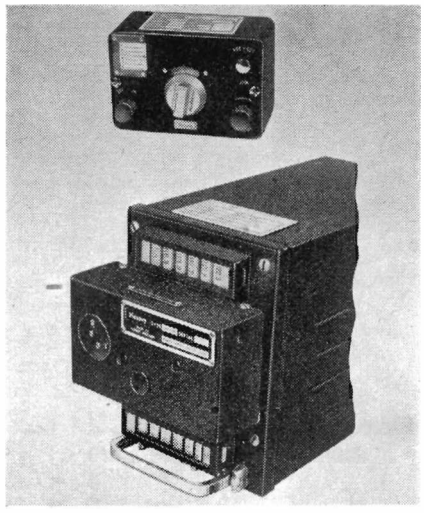
The principle employed is the absorption by mercury vapour of ultra-violet rays at a wavelength of 2,537 angstrom units. A low pressure Hanovia mercury resonance lamp is mounted at one end of a cylindrical chamber; the intensity of its radiation is recorded on a photocell at the other. The chamber is kept replenished with air drawn from the atmosphere to be tested by means of a blower. With clean air present the photocell will record maximum intensity; this is indicated by a zero recording on the microammeter dial in front of the instrument. Any admixture of mercury vapour reduces the transmission of ultra-violet rays along the cylinder and lowers the activity of the photocell. By means of a bridge circuit any decrease in the photocell response gives a positive reading on the microammeter dial, which can be operated at two different scales of sensitivity: 0 to 1,400 and 0 to 100 micrograms of mercury per cubic metre of air.

In use the mercury resonance lamp and air intake blower are kept running. Inlet air comes through rubber piping, the free end of which is taken into clean air (for calibration purposes) or to the test area (for readings). Piped connexions can be arranged so that the meter is used at a single control point covering several departments in a large building.

The instrument comprises a Post Office type rack mounting panel, in front of which are mounted: a microammeter, knobs for adjusting light, balance and sensitivity, a pilot light bulls-eye indicator for the ultra-violet-ray tube, on-off switches for mains, blower motor, and ultra-violet tube, a calibration push button and two fuses. Projecting from the back of the panel, and enclosed within a light welded sheet steel housing, is a sheet steel chassis, upon which the ultra-violet tube, photocell, blower motor, transformers, capacitors, resistors, etc., are mounted.

Hanovia, Ltd.,
Slough, Bucks.





Electrical Remote Control for Transmitter/Receiver

(Illustrated above)

IN addition to the manually operated remote control units for use in conjunction with the Plessey transmitter/receiver, type P.TR.61 C and D, a system of electrical remote control has now been developed. This facilitates installation of the transmitter/receiver in an aircraft without restriction as to position or distance from the control box, and permits the use of more than one control point with no additional installation complications.

The P.TR.61 C and D provides V.H.F. radio telephone communication facilities on any one of six crystal controlled channels within the aeronautical band 116-132Mc/s, and this remote control system provides, by the operation of a single control on the control box, for the selection of any one of these crystals, the entire procedure of tuning and crystal selection being carried out automatically. No restriction is imposed on the frequencies used, or on the order in which they appear. Each of the six pre-set frequencies may be positioned at any point within the coverage of the transmitter/receiver.

Provision is made for immediate access to carry out the pre-set adjustments of the tuning control; use of the tuning meter, connected to the monitor socket provided on the front of the equipment, allows any of the channels to be re-adjusted without removal of the equipment from the aircraft. Thus, ease of alteration of channel frequencies is preserved, and normal operation requires the use of only one control when changing channels.

Total weight of the remote control equipment, with one control box to S.B.A.C. standard dimensions is approximately 2¾lb, and current consumption is quoted as 3·5 amps.

The illustration above shows the transmitter/receiver with the electrical remote control adaptor below and the operator's control box at the top.

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

New G.E.C. Cathode-Ray Tube

A NEW cathode-ray tube, type 908 C.A.R.A., is announced by the General Electric Co., Ltd., for use in high speed oscillography. The tube, which utilizes electrostatic focusing and deflexion, has a 9cm diameter flat-faced screen coated with a highly actinic powder giving a blue fluorescence.

One stage of post-deflexion acceleration is employed, which enables the beam to be accelerated after the main deflexion has taken place. Connexions to the front plates are brought out of the envelope via side arms, while the connexions to the back plates and the third anode are taken through the base.

This new tube is the same as the Services type VCRX.294 and it has the same size and type of screen as the G.E.C. type 908 B.C.C., but differs in the following respects: it has only two side arms, which saves space where a number of tubes have to be used in multi-channel recording; it has a post-deflexion stage, and it is suitable for work demanding a better tube than the E.4412.B.9 but not justifying the use of a more elaborate type.

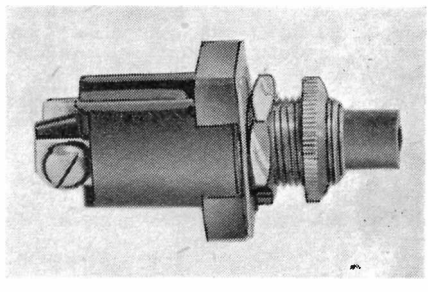
The operating conditions of the C.R.T. are as follows: it has a heater voltage of 4V, and heater current of 1·1amps; the first anode voltage is 2·0kV, the second 220V approximately, and the third 4kV; the post-deflexion accelerator voltage is 8kV, and the cut-off voltage −70V approximately; it has a back plate sensitivity of 0·11mm per volt and front plate sensitivity of 0·08mm.

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

New Arcolectric Switch

(Illustrated below)

THE new Arcolectric switch has been designed for door operation in refrigerators, wardrobes, etc. It is also suitable for use as a courtesy light switch in cars, and for certain other general applications as a limit switch.



This switch, catalogue No. S.930, is rated 1 amp 250 volt, and is designed for single ½in. hole fixing. It is biased normally "on", a very small depression of the push breaking the circuit and the rest of the movement of the push being "overrun."

The simplicity of the design—slow make and break—ensures that the switch will have a long life, and all current carrying parts are heavily silver-plated.

Arcolectric Signal Lamp Holder

(Illustrated above)

MESSRS. Arcolectric (Switches), Ltd., are producing a new signal lamp holder, catalogue No. S.L.92, which has been designed to meet the demand for a totally enclosed signal lamp that can be mounted in a small diameter fixing hole. In this case it can be fixed in a single hole—⅜in. diameter clearance in a panel up to ½in.

The holder is suitable for normal M.E.S. bulbs from 2 to 12 volts, having a glass envelope up to 11mm diameter. The coloured lens has a chromium plated bezel, and can be supplied in several colours, including red, green and amber. The insulation will resist a 2,000 volt flash test, and solder tag connexions are provided.

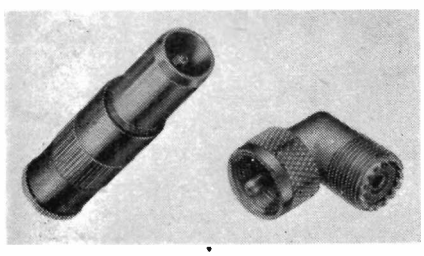
Arcolectric (Switches), Ltd.,
Central Avenue,
West Molesey, Surrey.

Precision Co-axial Connectors

(Illustrated below)

A NEW series of precision co-axial connectors have recently been produced by Transradio, Ltd., which are available in straight, elbow and T forms for co-axial cables having outside diameters between 0·36in. and 1·03in. Illustrated below are the straight and elbow type connectors.

Transradio, Ltd.,
138A Cromwell Road,
London, S.W.7.



Venner Hour Meters

(Illustrated top right)

THE Venner hour meters are designed to register the number of hours that an electrical circuit or machine has been functioning, and provide an accurate means of recording production times for costing purposes. They can also be used for indicating plant maintenance and servicing periods.

The meters are driven by the Venner synchronous motor, which ensures accurate time keeping being maintained by the supply frequency. They are therefore only suitable for use on A.C. controlled frequency supply systems. As the motor is of the self-starting type, the register is always correct, even in the event of a temporary supply failure. Cyclometer dials are fitted which read up to 9,999 hours and then repeat.

There are three types available working on 50 cycles A.C. with the following voltage supplies: 100-250 volts; 200-250 volts, and 400-500 volts. The first two voltages are available in either flush or surface mountings, and the last only in a surface mounting.

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

The "Elpico" Colour Filter

THE "Elpico" colour filter can be applied to the screen of any black and white television receiver to give a three colour picture with a certain elimination of glare.

The filter is attached to the screen with self-adhesive tape, which is supplied with the filter. It is non-inflammable, and is made in three sizes which will fit all standard screens from 9in. to 16in., including projection receivers.

Lee Products (Great Britain), Ltd.,
90 Great Eastern Street,
London, E.C.2.

A Tube Microphone

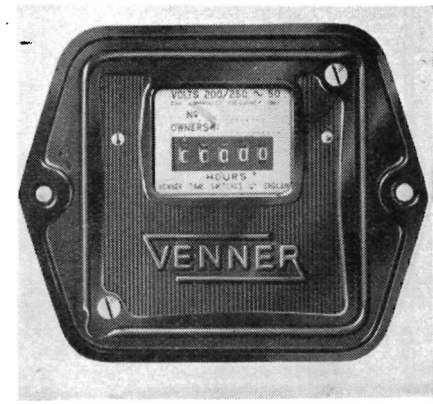
IN the new Tannoy tube microphone, the head and stand are blended together into one pencil-slim line, so that there is no microphone head to mask the user. Also a more durable design is achieved. It has a frequency response of 45 to 10,000c/s, and 45 to 8,000c/s ±3db, and an adjustable impedance of 50, 250 and 600 ohms. Its sensitivity is 81db below 1V at 600 ohms, measured in a sound field of 1 dyne per sq.cm. It has a base diameter of 10in., a minimum height of 3ft 6in., and a maximum height of 5ft 6in., with an effective head size of 1¼in. diameter and ½in. deep.

Tannoy Products, Ltd.,
Norwood Road,
London, S.E.27.

P.T.F.E. Winding Wires

POLYTETRAFLUOROETHYLENE covered winding wires are now being manufactured by Messrs. British Insulated Callender's Cables Ltd. Coils wound with these wires are capable of continuous operation at temperatures ranging from −75°C to +250°C. The insulating film of P.T.F.E. is normally one-thousandth of an inch thick.

Although, in the present stage of development, a certain amount of care is



required in the handling and winding of the wire, successful experimental coils are being produced by the Royal Aircraft Establishment.

Both production capacity and the raw materials required for its production are extremely limited, and at present its application is confined to service requirements having the support of the Ministry of Supply.

A wide range of P.T.F.E. insulated connecting wires and sleeving is also being manufactured. These cover the same range of working temperatures as the winding wires.

British Insulated Callender's Cables, Ltd.,
21 Bloomsbury Street,
London, W.C.1.

A Miniature Oscilloscope

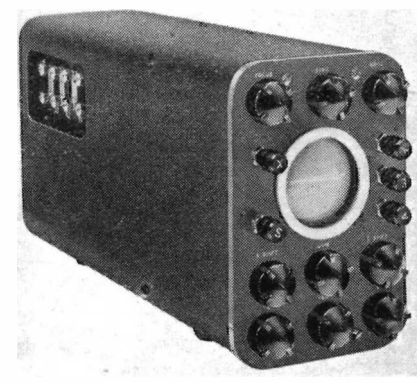
(Illustrated below)

THE new Belclere miniature oscilloscope measures 3½in. wide by 5½in. high by 10in. long and weighs just under 8lb. It uses a 1½in. cathode-ray tube to which the time-base is applied symmetrically.

A single stage A.C. coupled Y amplifier is provided, this can be arranged, by operation of a switch, to give a sensitivity of 100mV/cm from 10c/s to 150kc/s or 500mV/cm over the range of 10c/s to 3Mc/s.

A hard valve time-base is used and the output from this is available at the X terminal; it has a frequency range of from 10 to 50,000 sweeps per second. The flyback is suppressed.

John Bell and Croyden,
117 High Street,
Oxford.



Notes from the Industry

The 4th Conference on Industrial Physics, arranged by the Institute of Physics, will take place in the Royal Technical College, Glasgow, from June 24-28, 1952. The subject of the conference is "Physics in the Transport, Shipbuilding and Engineering Industries." In connexion with the conference an exhibition of instruments, apparatus and books relevant to this subject will be held, and more than 70 industrial firms and Government departments have accepted invitations to take part.

The programme of the conference includes lectures and discussions on metal physics, meteorology, the education and training of industrial physicists in Scotland, sound reproduction, physics in naval architecture, physics in transport, automatic control of industrial processes, and noise and its suppression.

The conference will be opened by Lord Bilsland, President of the Scottish Council; the principal speakers include Sir Andrew McCance (who is chairman of the organizing committee of the conference) and Sir Robert Watson-Watt.

Full particulars, forms of application for conference membership, and tickets of admission to the exhibition may be obtained from the Secretary, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

B.B.C. Engineering Division Appointments. The B.B.C. announces the following new appointments in the Engineering Division: Mr. F. Axon, D.C.M., has become Senior Superintendent Engineer, External Services; Mr. H. W. Baker, A.M.I.E.E., Superintendent Engineer, Television Studios; Mr. T. H. Bridgewater, M.I.E.E., Superintendent Engineer, Television Outside Broadcasts; Mr. H. Walker, O.B.E., A.M.I.E.E., Head of Technical Operations, Television Service; Mr. M. H. Hall, Engineer-in-Charge, Television Studios; Mr. W. D. Richardson, Engineer-in-Charge, Television Outside Broadcasts, and Mr. F. Williams, B.Sc.(Hons.), M.I.E.E., Senior Superintendent Engineer, Home Broadcasting.

Decca Radar Ltd. announce that they have formed a new division of the Company, to be known as the Radar Applications Division.

The work of this new department will be principally concerned with the study of marine radar, harbour radar and associated systems, and in particular with providing a planning service for harbour radar authorities and others in order that their operational requirements may be met effectively.

Wenvoe Television Transmitting Station. The B.B.C. announces that it is hoped to open the new television transmitting station at Wenvoe, near Cardiff, on medium power, on August 15. The Postmaster-General, Earl De La Warr, P.C., has agreed to perform the opening ceremony.

Cambridge Summer School in Automatic Computing. A Summer School in programme design for automatic digital computing machines will be held in the University Mathematical Laboratory at Cambridge during the period September 16 to 26, 1952.

It is now widely recognized that these machines can make a large contribution towards the solution of a great variety of problems in mathematics, physics, engineering and other subjects. The course will give a basic training in the mathematical use of the machines, dealing with the processes employed and their embodiment in programmes which specify the operation in detail. Lectures and practical classes will be held in the design of programmes for the Edsac, the machine which has been built in the laboratory. It will be shown how the same principles may be applied in designing programmes for other machines.

A detailed syllabus and form of application for admission may be obtained from G. F. Hickson, M.A., Secretary of the Board of Extra-Mural Studies, Stuart House, Cambridge, to whom the completed application form should be returned not later than July 14, 1952.

Marconi—Commemorative Plaque. A plaque in memory of Marconi was recently placed outside 71 Hereford Road, Paddington. The inscription reads: "London County Council. Guglielmo Marconi 1874-1937. The pioneer of wireless communication lived here in 1896-1897."

The German Radio and Television Exhibition 1952 will be held in Düsseldorf from August 22 to 31. All firms located in the Federal German Republic and in Western Berlin which produce radio and television equipment and accessories will be represented at the exhibition. The exhibition will feature ultra short-wave radio and television, while the German Post Office and German Amateur Radio Club will both have large exhibits. Further information can be obtained from Nordwestdeutsche Ausstellungsgesellschaft M.B.H., Düsseldorf, Ehrenhof 4.

Acknowledgments. In the article "A Recording and Integrating Flowmeter" by D. C. Pressey, B.Sc., which appeared on page 112 of the March, 1952 issue, the section headed "Flow-rate Transducer" was contributed by Dr. M. G. Epstein of the Nuffield Department of Anaesthetics, and it is to him that the reference (1940 Unpublished) refers. In the May issue on page 224 there appears an article on "A Versatile Phase-Angle Meter" by G. N. Patchett, Ph.D., B.Sc., A.M.I.E.E., who would like to make an acknowledgment to the Bradford Technical College where the work for this article was carried out.

PUBLICATIONS RECEIVED

VARIABLE CAPACITORS AND DRIVES is a catalogue giving schematic diagrams and some information on the standard types of capacitors, etc., manufactured by Jackson Bros. (London) Ltd., Kings Way, Waddon, Surrey.

THE SITING OF DIRECTION FINDING STATIONS is the D.S.I.R. Radio Research Special Report No. 22, and studies the effect of various site imperfections on instruments operating in the frequency range of 100kc/s to 300Mc/s. The types of instruments considered are mainly those with loop or Adcock aerial systems, and special attention is given to the calibration of direction finders. The main conclusions of the report are summarized in tables showing the minimum tolerable distances for different objects when it is desired to achieve specified accuracies. Her Majesty's Stationery Office, Kingsway, London, W.C.2, price 1s. 6d., postage 1½d.

FLUID RUBBER COMPOSITIONS, THEIR PREPARATION AND APPLICATIONS is a leaflet that describes fluid rubber compositions, containing neither water or volatile solvent, which can be poured and set to form elastic, soft rubber or hard rubber articles. The principles underlying the preparation of these compositions, the types of final products that can be obtained, and their applications are outlined. The Report is issued by the British Rubber Development Board for the Rubber Technical Developments Ltd., 78 Bridge Road East, Welwyn Garden City, Herts.

SOLWAY FLOWRATORS VARIABLE AREA FLOW METERS is a catalogue of the equipment available from this firm for indicating, recording, integrating, transmitting and automatically controlling the flow rates of liquids and gases. The catalogue is well produced, and copies are available from Solway Flowrators Ltd., Abbey Road, Park Royal, London, N.W.10.

E.M.I. SCHOLARSHIPS—FOUR YEAR TRAINING SCHEME IN ELECTRONIC ENGINEERING is a brochure produced by E.M.I. Institutes to provide details of this course. It mentions the type of career available in the E.M.I. organization, and outlines the training undertaken in the course. Copies of the brochure can be obtained from the Principal, E.M.I. Institutes, 10, Pembridge Square, London, W.2.

REPORT OF THE TIN RESEARCH INSTITUTE FOR 1951 mentions a number of researches which reached the stage of commercial development during the year, foremost among which were tin-nickel electroplate for domestic metalware, automobile parts and electrical appliances, and tin-zinc for mechanical parts and fitments of cars, cycles, tools and machinery. Research concerning bearing alloys, tinplate, production of bars, rods and thick-walled tubes of bronze, and a new pewter were also described in the Report. Twelve publications issued for the first time in 1951 are listed at the end of the Report. It is available, free of charge, from the Tin Research Institute, Fraser Road, Perivale, Greenford Middx.

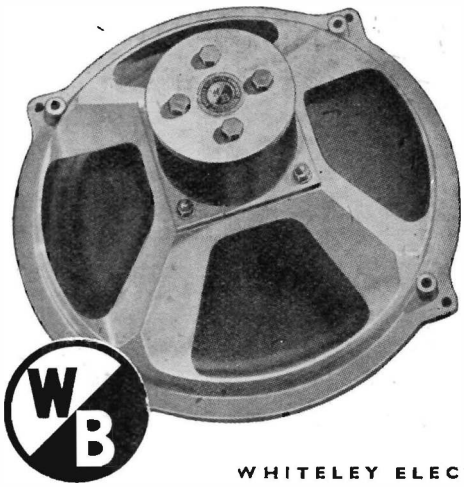
"95"—BIRLEC HEAT TREATMENT DIVISION is a small brochure issued to describe the firm's heat treatment service. It gives brief notes on the copper brazing process, small heat treatment requirements, and research carried out by this division of Birlec, Ltd. Copies of the brochure are available free from the Heat Treatment Division, 95 Tyburn Road, Erdington, Birmingham, 24.

LECTURE CHARTS AND NOTES ON CATHODE-RAY TUBES FOR TELEVISION deals with the subject from the viewpoint of historical development. The charts are large and clear, the first one being of J. J. Thomson's design of 1897 and the last of Ediswan Mazda Type CRM.151, 1950. The charts and notes have been produced to help lecturers, schoolteachers and instructors, and copies are available free from the Edison Swan Electric Co., Ltd., 155 Charing Cross Road, London, W.C.2.

PLESSEY LOUDSPEAKER CATALOGUE describes their new shrouded loudspeakers, and outlines the advantages available from this range. The catalogue is well presented in this firm's usual style, and is available to manufacturers from the Plessey Co., Ltd., Ilford, Essex.

● LET OTHERS SPEAK ABOUT *Stentorian* SPEAKERS

These unsolicited letters are typical of those received from Stentorian users — they are evidence of the benefits of specialisation. Every part of our speakers is made within the organisation, thus enabling us to maintain the standard of quality that has been famous for twenty-five years.



" I am very glad to say that this speaker is giving me great satisfaction. Its frequency response, transient response and power handling capacity are truly remarkable, particularly for such a moderately priced speaker. It surpasses most other speakers I have heard, even considerably more costly ones."

●

" It will doubtless be of interest to you to learn that this particular W/B 10" loudspeaker was purchased during 1928 and continues to give excellent service."

●

" It surprises me how you get a single cone unit, like the S.1012, to cover such a wide frequency range. Every note and syllable comes out with such natural realism. For instance, the 'ting' of the triangle and clash of the cymbals are very clearly heard — but not at the expense of the bass, for that is there too in correct proportion, resulting in a very good balance of tone."

●

" Thanks once again for a really fine speaker (in fact the finest speaker) in my humble opinion."

●

" I must congratulate you on producing the finest speaker unit I have had the privilege to own. Your claims regarding the performance of the 10" Concentric Duplex speaker are not in any way exaggerated. I find it ideally suited for domestic use."

● **Full details and prices on request.**

WHITELEY ELECTRICAL RADIO CO. LTD MANSFIELD NOTTS.

FERROXCUBE

FERROMAGNETIC FERRITE

FOR TELEVISION

THE improvement in television components, with their smaller size and greater efficiency, is largely due to Ferroxcube, the new Mullard magnetic core material.
The uses of Mullard Ferroxcube in the production of TV components fall into these three main groups:

LINE OUTPUT TRANSFORMER CORES

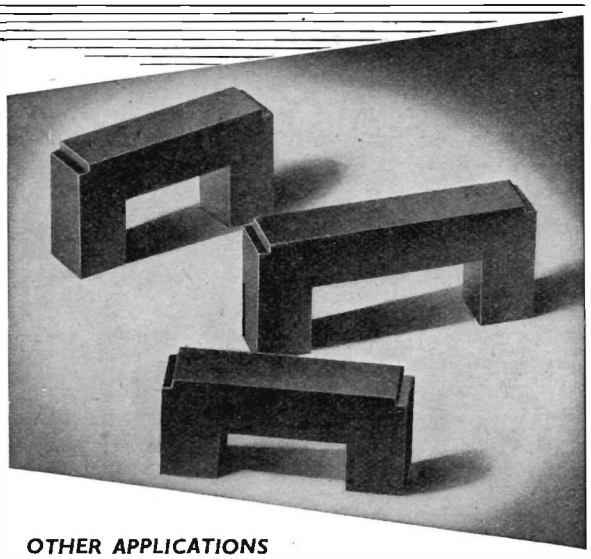
Since the advent of wide-angle television tubes, with the accompanying demand for increased E.H.T. supplies, the need for line output transformers of the highest possible efficiency has been greater than ever. Mullard Ferroxcube, with its low iron losses, completely fulfils this need — also facilitating the assembly of small, compact transformer units by means of solid, non-laminated U-shape cores.

DEFLECTION COIL YOKES

Mullard Ferroxcube cores in ring form are ideal for producing the magnetic circuit around deflection coils. Used in this way, Mullard Ferroxcube makes possible the construction of efficient deflector coils with a high Q factor. In order to simplify assembly problems, these ring cores are supplied either in the form of a complete circle, as two semi-circles, or as castellated yokes.

LINEARITY AND PICTURE WIDTH CONTROLS

Mullard Ferroxcube can very conveniently be extruded into rods and tubes. In this form it is ideal for use in linearity and picture width controls, providing a smooth control in a compact assembly.



OTHER APPLICATIONS

In addition to its uses in television receivers, Mullard Ferroxcube is also being widely employed in line communications, radar, and other specialised electronic equipments. The purposes for which it is already being most successfully applied in such equipments include filter networks, wide band transformers, magnetic amplifiers, and pulse transformers.

PLEASE WRITE FOR FULL DETAILS

Mullard *FERROXCUBE*

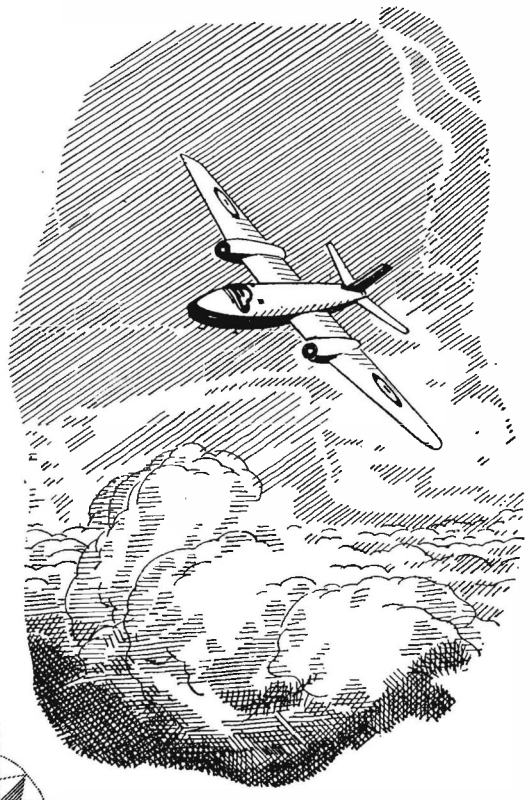
FERROMAGNETIC FERRITE

MULLARD LIMITED · CENTURY HOUSE · SHAFTESBURY AVENUE · LONDON · W.C.2.
(MF376)

MARCONI

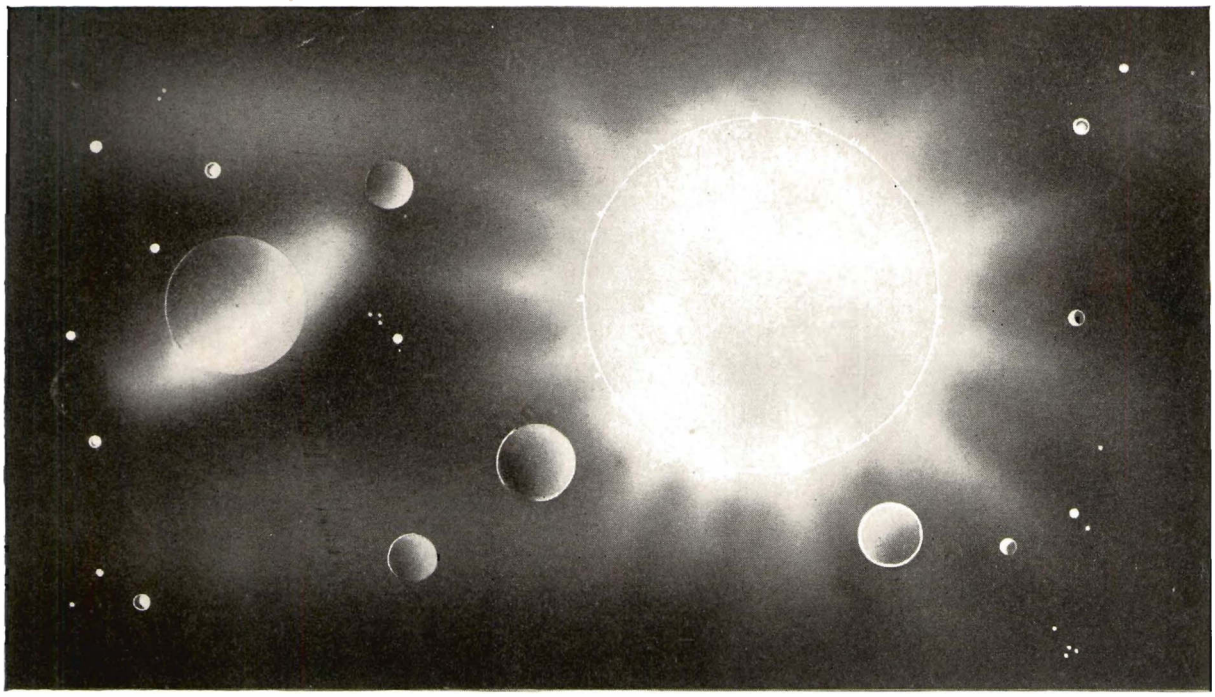
serves

mankind



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

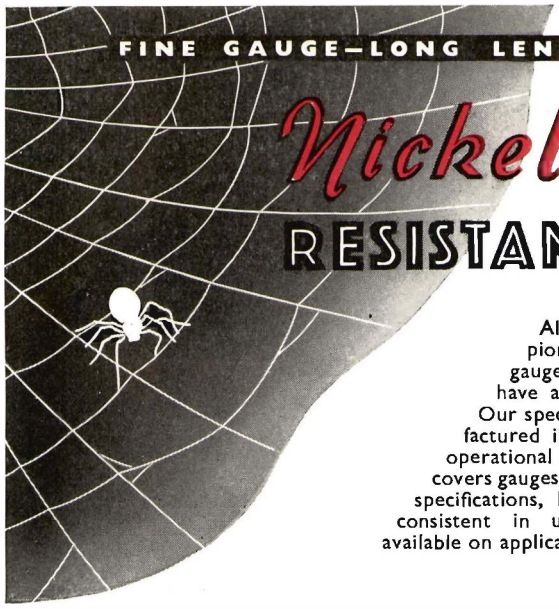
MARCONI'S WIRELESS TELEGRAPH COMPANY LTD · CHELMSFORD · ESSEX



Astronomically Speaking

If our total production of all types of winding wires in the last fifty years could be tied end to end, it would stretch up to the sun — 93 million miles away — and most of the way back again.
So now you have a fair idea of our total production in length — or have you?
We just mention this astronomical data *en passant*: the idea of running up to the face of the sun in a temperature of some 10,000°F doesn't appeal to us in the least. Making and keeping more and more satisfied customers is our primary interest.
The largest manufacturers of fine enamelled wire in the world.

CONNOLLYS (BLACKLEY) LTD. MANCHESTER 9 **Tel: CHEetham Hill 1801**
LONDON OFFICE: 34 Norfolk St., London, W.C.2 TEMple Bar 5506
BIRMINGHAM OFFICE: 19 Bent Avenue, Quinton, Birmingham, 32 WOOdgate 2212



FINE GAUGE—LONG LENGTHS

Nickel Chrome RESISTANCE WIRES

Although the spider may have pioneered the production of a fine gauge strand of continuous length we have added refinements of our own. Our speciality is Resistance Wire manufactured in long lengths to reduce your operational changes. Our normal range covers gauges down to 50 s.w.g. to customers' specifications, but even finer gauges, equally consistent in uniformity and accuracy, are available on application.

LONDON AGENT : Cotsil, Ltd., 80 Mortimer St., London, W.1. Telephone : Langham 1071/2.

Cromaloy V

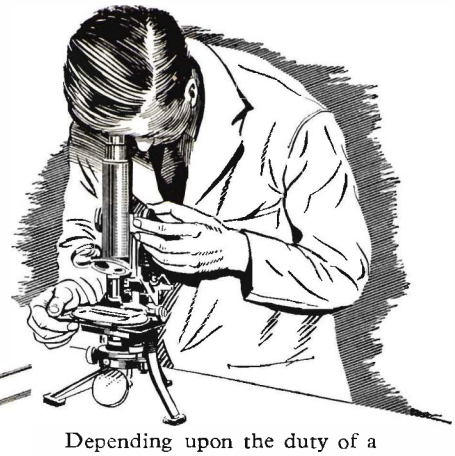
FOR CONSISTENCY

A. C. SCOTT & CO. LTD., CROMALOY HOUSE, CITY RD., MANCHESTER

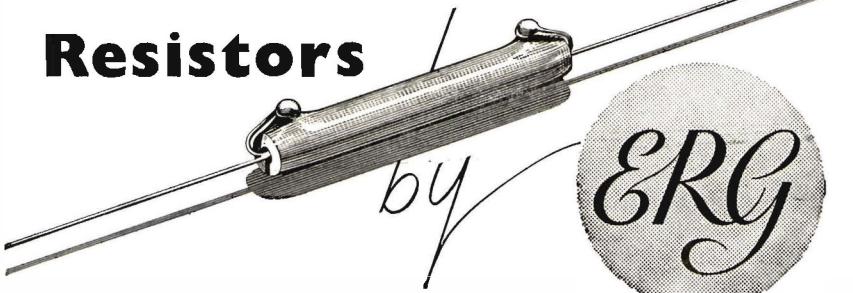
dm AS 13

CONTROL

The manufacture of resistors is *not* like "shelling peas". The reverse is true. Specialists alone fully appreciate the diverse problems. A standard Service-type vitreous-enamelled resistor, for example, is completed after twenty separate operations, each of which calls for close control to ensure maximum reliability and stability in the field. The microscope (x 100) is constantly used to examine the standard of these individual operations and is evidence of our insistence that 100% efficiency is maintained throughout production.



Resistors by ERG



(Type Approved for all Service Departments)

Depending upon the duty of a resistor, special protective coatings are available:

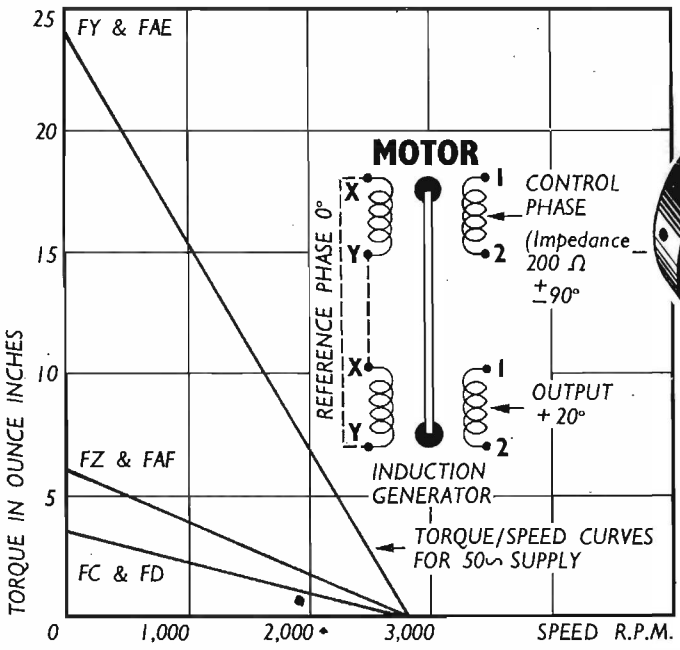
VITREOUS · CEMENT
SILICONE · LACQUER

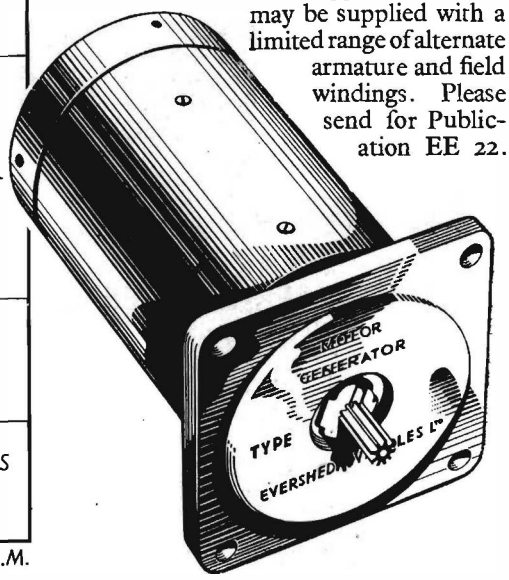
Full information on the application of ERG Wire Wound Resistors is to be obtained from our London Sales Office: 10 Portman Square, London, W.1. (Welbeck 8114).

ERG INDUSTRIAL CORPORATION LTD · MATTHEW STREET · DUNSTABLE · BEDS.

EVERSHED F.H.P. MOTORS

TYPICAL A.C. SERVO MOTORS FOR ELECTRONIC CONTROL





All motors are rated for a standstill temperature rise of 55° C. Motors may be supplied with a limited range of alternate armature and field windings. Please send for Publication EE 22.

FRAME SIZE	MOMENT OF INERTIA OZ INS.²	STALL TORQUE OZ. INS.²	REFERENCE PHASE			CONTROL PHASE	OUTPUT	GENERATOR		
			SUPPLY		WATTS			REFERENCE PHASE		OUTPUT PER 1000 RPM (10K LOAD) VOLTS
			V	C/S		WATTS	WATTS	VOLTS	C/S	
FC	0·16	4·0	50	50	8·6	11	2·3	—	—	—
FD	0·21	4·0	50	50	8·6	11	2·3	50	50	0·75
FZ	0·27	6·0	50	50	12	12	4·3	—	—	—
FAF	0·32	6·0	50	50	12	12	4·3	50	50	0·75
FY2/B	0·6	22·0	50	50	35	35	16	—	—	—
FAE	0.65	22·0	50	50	35	35	16	50	50	0·75

EVERSHED

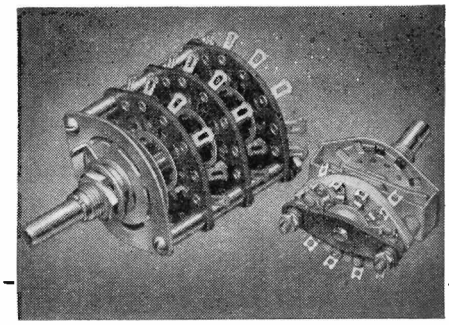
EVERSHED & VIGNOLES LIMITED

ACTON LANE WORKS - CHISWICK - LONDON - W.4.

Telephone : Chiswick 3670 Telegrams : Megger, Chisk, London Cables : Megger, London.

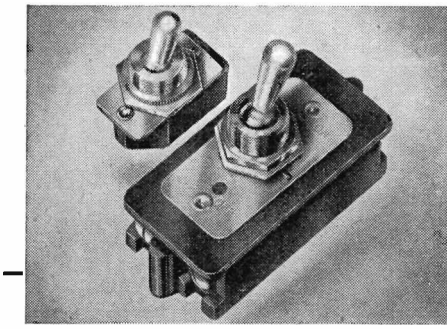
6/85

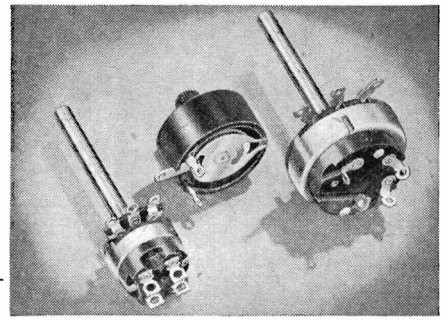
Service to the ELECTRONICS INDUSTRY



OAK SWITCHES are supreme in the radio and electronic fields. OAK—the superior wafer-type switch — incorporates self-cleaning double-contact clips and floating rotors ensuring self-alignment.

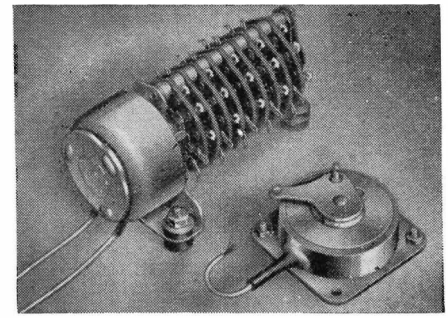
CUTLER-HAMMER SWITCHES are famous in the electronic and electrical industries throughout the world for reliability and efficiency. They are available in a wide range of ratings and with several types of operating mechanisms such as lever, slider, trigger, or plunger actions.





POTENTIOMETERS are ruggedly built for long and reliable service under the most exacting conditions. There is a full range of composition types, with or without switches, and wire-wound types for television applications.

ROTARY SOLENOIDS are compact, robust, and efficient electro-mechanical devices with a powerful snap-action rotary movement. As circuit selectors—with Oak switch sections — they have numerous applications in the electronic and telecommunication fields.



N.S.F. LIMITED • KEIGHLEY • YORKS

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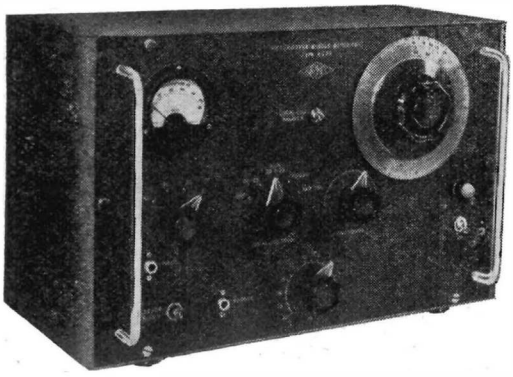
AIRMEC

BRIDGE DETECTORS

BRIDGE OSCILLATOR AND DETECTOR TYPE 703

- **Oscillator Frequency :** 1,500 c/s.
- **Oscillator Output :** 100 milliwatts.
- **Output Impedance :** High : 3,000 ohms. Low : 100 ohms.
- **Amplifier Sensitivity :** Low Impedance : 40 microvolts for 10% f.s.d. High Impedance : 200 microvolts for 10% f.s.d.
- **Indication :** Both meter and phones.
- **Input Impedance :** High : 1,500 ohms. Low : 60 ohms.
- **Accuracy :** A reading accuracy of 1% is obtainable on bridges using 1000 : 1 ratio arms, and a correspondingly greater accuracy where smaller bridge ratios are employed.



BRIDGE HETERODYNE DETECTOR TYPE 775

- **Frequency Range :** 6.5 to 751 kc/s.
- **Beat Frequency :** 1 kc/s.
- **Selectivity :** Not less than 30 db discrimination at 1 kc/s off tune.
- **Sensitivity :** Readable meter deflection for 5 microvolts input. Audible note in phones for 1 microvolt input.
- **Input Conditions :** Transformer having screened and floating primary winding.
- **Attenuation :** 0 to 60 db in 20 db steps. 0 to 20 db slidewire.

Full details of this or any other Airmec instrument will be forwarded gladly upon request.

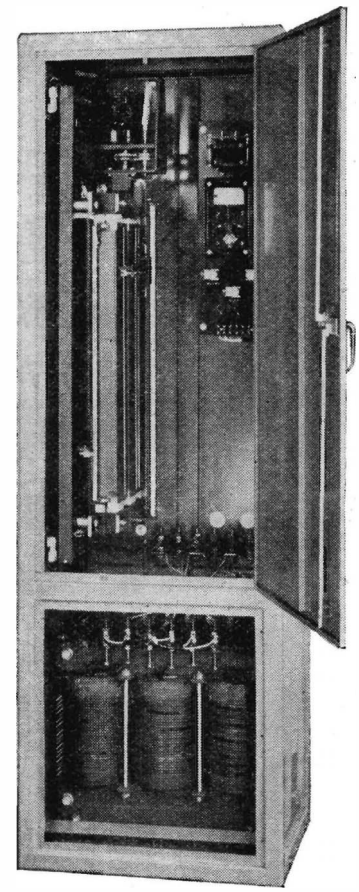
AIRMEC LABORATORIES **LIMITED**

HIGH WYCOMBE · BUCKINGHAMSHIRE · ENGLAND

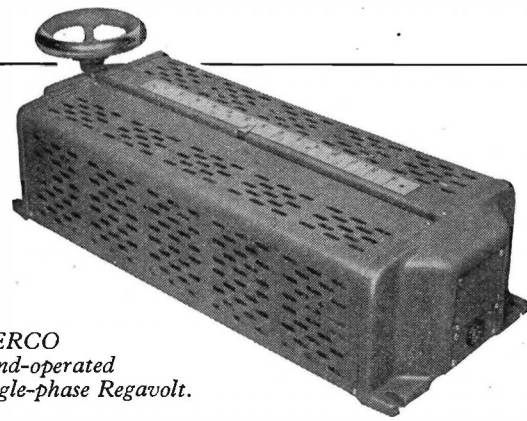
TEL.: HIGH WYCOMBE 2060 *CABLES: AIRMEC HIGH WYCOMBE*

Is VF* *spoiling your output?*

Whenever the successful operation of apparatus or plant depends on an absolutely constant mains voltage, then "V.F."* (Voltage Fluctuation) can have disastrous effects. Every variation results in loss of efficiency, and output suffers accordingly. That is why BERCO and B.P.T. voltage and current regulating equipment plays an important part in well planned organisations all over the world.



Typical BERCO/BPT three phase Automatic Stabiliser 30 kVA.



BERCO hand-operated single-phase Regavolt.

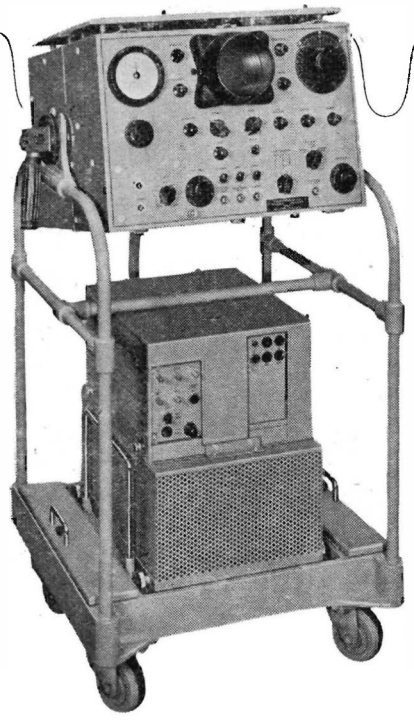
For constant voltage use a model from the wide range of Automatic Stabilizers made by British Power Transformer Co. Ltd., for single and three phase supplies.
For variable voltage select a "Regavolt" from the wide range of models made by The British Electric Resistance Co. Ltd. Interesting information and full performance details given in booklet No. C1011.

THE BRITISH ELECTRIC RESISTANCE CO. LTD.
BRITISH POWER TRANSFORMER CO. LTD.
Queensway · Ponders End · Middlesex
Telephone : HOWard 1492 Telegrams : "Vitrohm Enfield"

B.R./BP./1011T

E.M.I WAVEFORM MONITORS

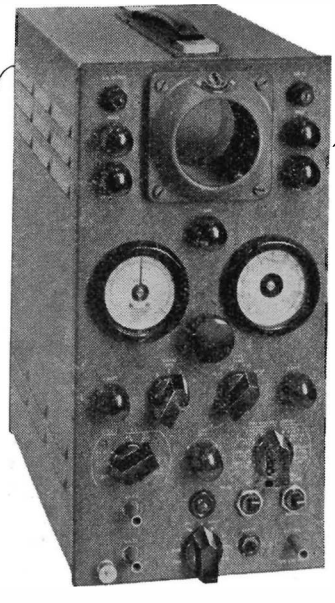
THE PRECISION MEASURING OSCILLOSCOPES CHOSEN BY THE LEADING RESEARCH AND INDUSTRIAL LABORATORIES



TYPE 3794T

- High Speed Time Base. Sweep speeds up to 33 cms/microsecond.
- New type C.R.T. with post deflection accelerator enables very short duration pulses recurring at frequencies down to 50 c/s to be displayed and measured.
- Measurement Facilities.
  VOLTAGE from ± 0.05 to ± 500 within ± 1%.
  TIME from 0.01 microsecond to 50 milliseconds within ± 2½%.
- Dual input D.C. coupled, vertical deflection Amplifier. Time of rise 0.07 microsecond.
- Sensitive Trigger or Synchronising Amplifier, with phase-amplitude selective facilities.
- Gain and Delay Unit — This stabilised video amplifier incorporates a delay cable so that the leading edge component of short duration low amplitude waveforms can be displayed and measured.

TYPE WM3



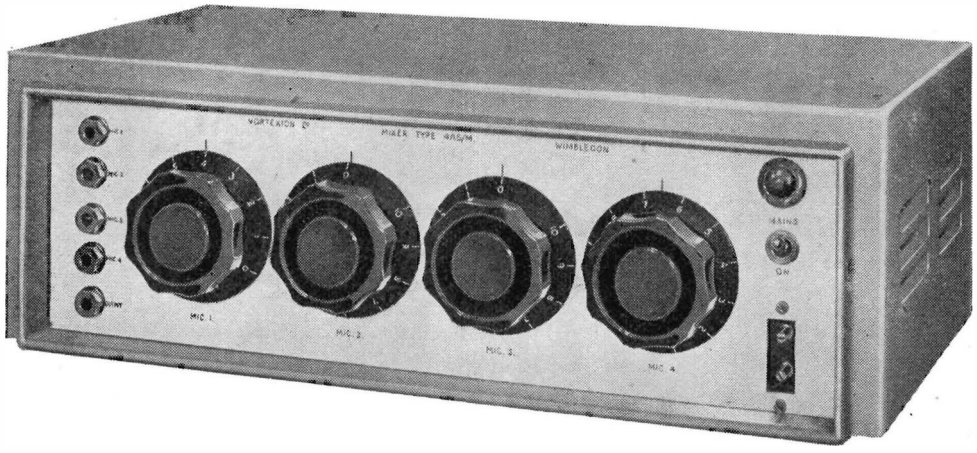
- Miniaturised construction ; dimensions 15″ x 7½″ x 14″.
- Dual input, D.C. coupled, vertical deflection Amplifier. Time of rise 0.3 microsecond. Sensitivity from 13 millivolts/c.m. to 10 volts/c.m.
- Voltage measurement from ± 0.002 to ± 500 within ± 2½%.
- Time measurement from 0.5 microsecond to 40 milliseconds within ± 2½%.
- Sensitive Trigger or Synchronising Amplifier with phase-amplitude selective facilities.

E.M.I. FACTORIES LIMITED

HAYES · MIDDLESEX

EF7

FOUR-WAY ELECTRONIC MIXER



This unit has 4 built-in, balanced and screened microphone transformers, normally of 15-30 ohms impedance. It has 5 valves and selenium rectifier supplied by its own built-in screened power pack : consumption, 20 watts.

Suitable for recording and dubbing, or large P.A. installations, since it will drive up to six of our 50 watt amplifiers, whose base dimensions it matches. The standard model has an output impedance of 20,000 ohms or less, and any impedance can be supplied to order.

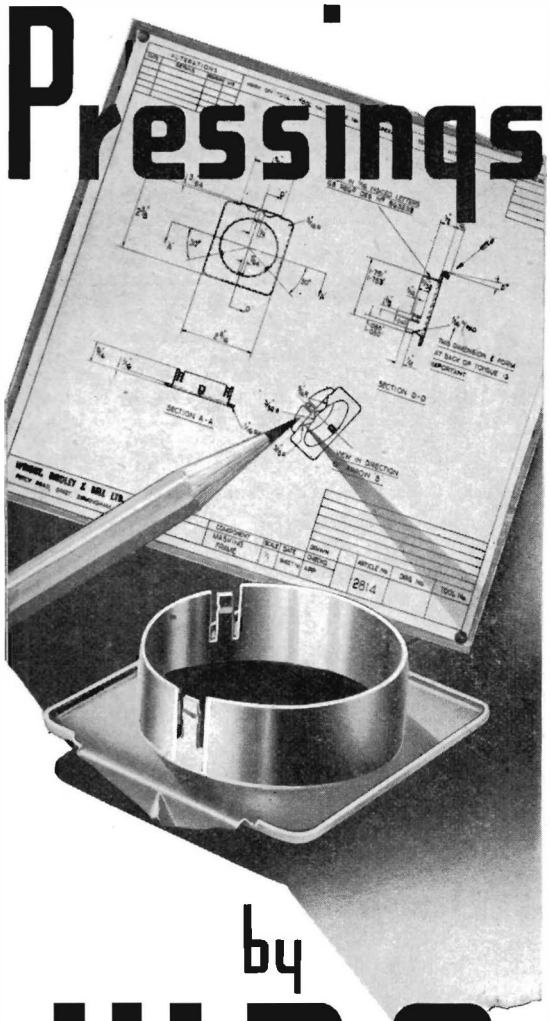
Manufactured by :

VORTEXION LIMITED

257-263, THE BROADWAY, WIMBLEDON, LONDON, S.W.19

Telephones : LIBerty 2814 & 6242-3 *Telegrams : "Vortexion, Wimble, London."*

Precision Pressings



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W-B-G

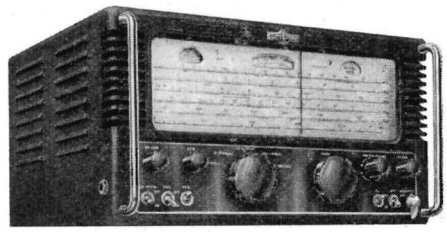
IN *ALL* METALS FOR *ALL* INDUSTRIES

WRIGHT, BINDLEY & GELL LIMITED

TELEPHONE VICTORIA 2295/6/7 (PBX) · GREET · BIRMINGHAM, 11 TELEGRAMS BINDLEY, B'HAM, 11

EDDYSTONE

FINE COMMUNICATION RECEIVERS



MODEL "680X"

- Fifteen Valves
- Two R F Stages
- Two I F Stages
- Separate Oscillator
- Variable Selectivity
- Crystal Filter
- "S" Meter
- Push-pull Output
- Polychromatic Finish
- Robust Construction

MODEL "750"

- Double Superheterodyne
- Eleven Valves
- High Sensitivity
- Variable Selectivity
- Free from Images
- Separate Gain Controls
- Large Dial with Linear Scales
- Mechanical Bandspread

For full information please write to the Manufacturers :—

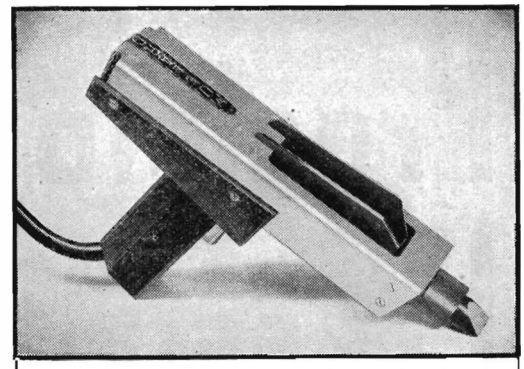
STRATTON & Co. Ltd.

EDDYSTONE WORKS, BIRMINGHAM, 31

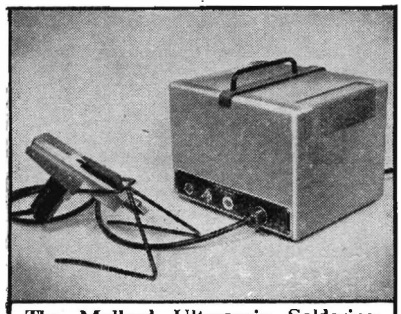
AN ULTRASONIC SOLDERING IRON

Can be used for soldering aluminium, and other metals that form refractory oxides

THE problem of soldering metals that form refractory oxides has now been overcome.
A new soldering iron, developed by Mullard Ltd., destroys oxide film by ultrasonic stimulation and provides a "clean" metallic surface.
This means that perfect soldering of aluminium, and other metals, can now be achieved without scraping or brushing molten metals. Standard soft solders can be used. And no flux is needed.
A small electronic amplifier supplies the ultrasonic power. Two controls, a mains and a trigger switch, ensure simplicity of operation. Unskilled workers can use the apparatus without discomfort, since the ultrasonic frequency used is inaudible to the human ear. Full information about the Mullard Ultrasonic Soldering Iron—the only commercial model in the world — is available on request.



The soldering iron has a nickel silver bit driven by a magnetostriction transducer. The transducer is arranged to run at its natural resonant frequency by a feed-back system. A conventional low voltage winding heats the soldering bit.



The Mullard Ultrasonic Soldering Iron and Amplifier. The unit operates from A.C. mains and is robustly made to suit workshop conditions.

Mullard

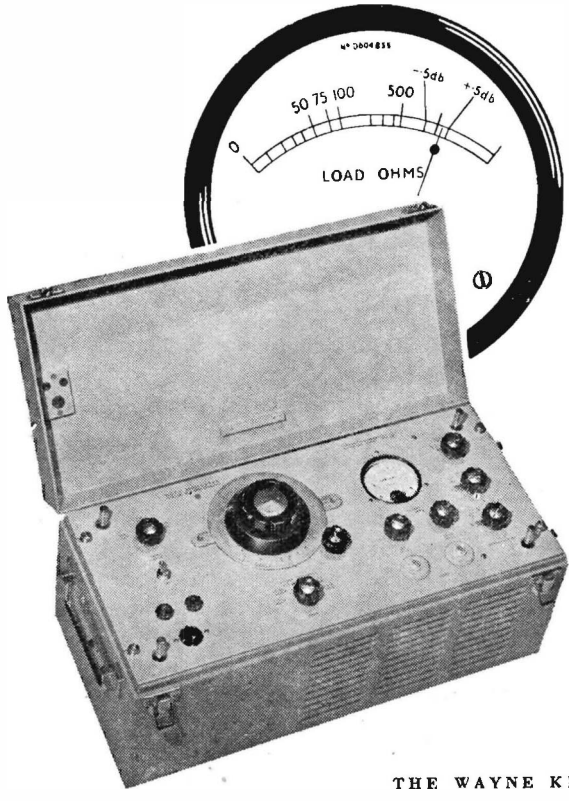
CONDUCTIVITY EQUIPMENT · POTENTIOMETRIC TITRATION APPARATUS · ELECTRONIC POLAROGRAPHS · TEMPERATURE CONTROLLERS · UNIVERSAL MEASURING BRIDGES · VALVE VOLTMETERS F.M. SIGNAL GENERATORS · OSCILLOSCOPES

NORTHERN AGENT: F. C. Robinson & Partners, Ltd., 287, Deansgate, Manchester, 3
MIDLAND AGENT: Hadley Sound Equipments Ltd., 72, Cape Hill, Smethwick. *Tel.: Smethwick 0977.*
SCOTTISH AGENT: Land, Speight & Co. Ltd., 73, Robertson Street, Glasgow, C.2.

Mullard Ltd., Equipment Division, Century House, Shaftesbury Avenue, London, W.C.2. Telephone: GERrard 7777

Mullard

(MI.340)



VIDEO-FREQUENCY OSCILLATOR

TYPE 0222

7 kc/s to 8 mc/s

Outstanding features of the Wayne-Kerr 0222 Video-Frequency Oscillator are its low harmonic content and unusual stability—both of frequency and amplitude. It can, in fact, be switched to any of the six ranges between 7 kc/s and 8 mc/s with negligible change in output level. A further advantage is its special facility for indicating the modulus of the load impedance to which it is connected. This instrument is easily carried about in its transportable case, or it can be supplied for rack mounting if preferred.

Wayne Kerr

THE WAYNE KERR LABORATORIES LIMITED, NEW MALDEN, SURREY

for reliable Radio Communications

YOU CAN'T BUY BETTER!

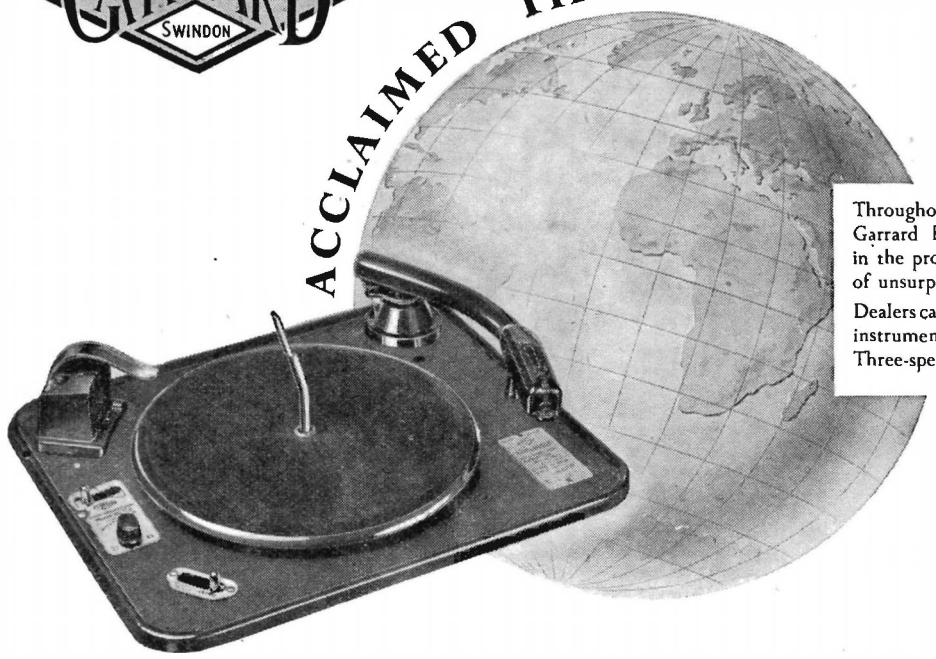
A COMPREHENSIVE RANGE OF UNITS
IS AVAILABLE COVERING ALL COMMUNICATION
REQUIREMENTS. ASK FOR LEAFLET Q.C. 5012 (R).

Be sure that the Quartz Crystal Units in your radio equipment are the best obtainable, for they are the most critical components

SALFORD ELECTRICAL INSTRUMENTS LTD · SALFORD 3 · LANCS
A SUBSIDIARY OF THE GENERAL ELECTRIC CO. LTD. OF ENGLAND

GARRARD
SWINDON

ACCLAIMED THE WORLD OVER



Throughout the Years the name of Garrard has reigned supreme in the production of Turntable Units of unsurpassed quality.

Dealers can unhesitatingly recommend instruments fitted with Garrard Three-speed Self Changing Units.

STYRAFOIL REGD.

AN EXCELLENT H.F. DIELECTRIC

specially suited for condensers

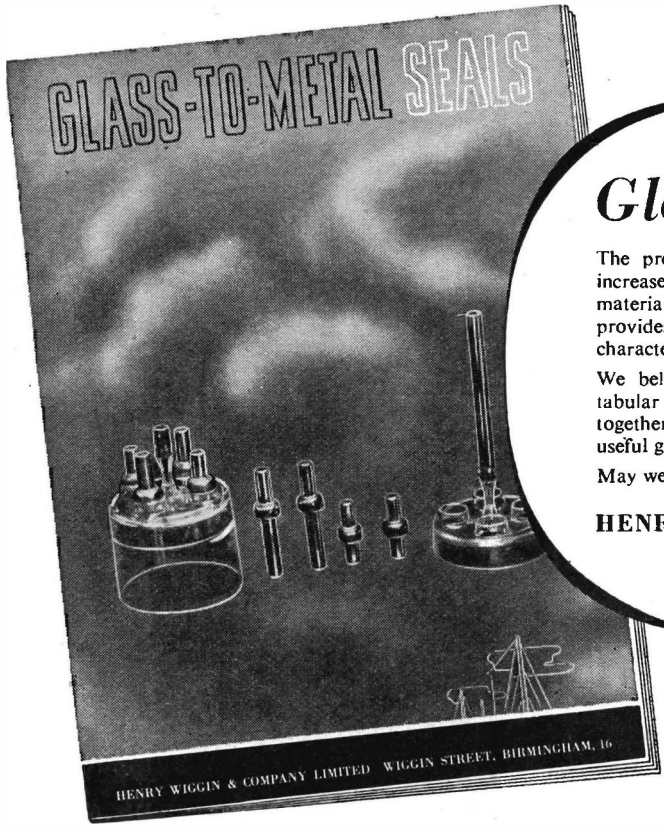
Styrafoil is an orientated film of polystyrene, possessing outstanding electrical characteristics (Power factor ·0003—·0005; permittivity 2·6—2·7; dielectric strength 4000 volts/mil at ·002" thickness). It is supplied in various thicknesses from ·0004" (10 micron), and in slit widths.

Prompt delivery. Samples available on request.

BX PLASTICS LTD., CHINGFORD, LONDON, E.4.

LARkswood 5511.

T.A. 4447



Glass-to-metal Seals

The present abnormal conditions of supply have placed increased emphasis on the correct choice of constructional materials. As an example, the Nilo range of nickel-iron alloys provides a range of compositions each having distinctive characteristics and developed to meet a specific requirement.

We believe that our revised publication, which includes tabular data on the properties of the various grades of alloy, together with examples of their industrial use, will prove a useful guide to the selection of the correct grade of material.

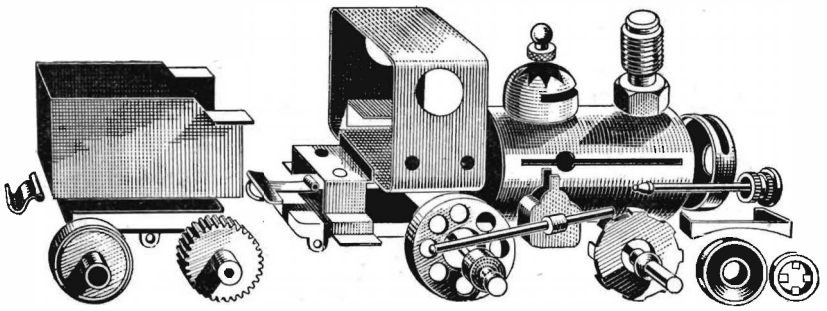
May we send you a copy?

HENRY WIGGIN & COMPANY LIMITED

Wiggin Street, Birmingham 16

56/NL/9

HIGH SPEED AUTOMATICS



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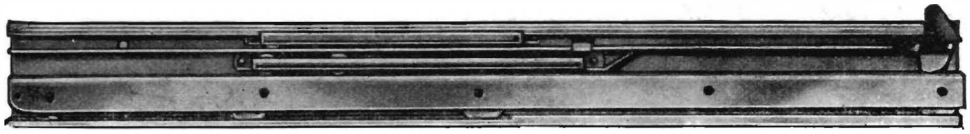

Type A Slides as above supplied in 15⅝", 17⅝", 21", 23⅝", 25¼" and 27¼" lengths. Heavy type A Slides supplied in lengths 23⅝", 28¼", 32" and 37". Type A series case strips may be drilled and countersunk or provided with ears or lugs.

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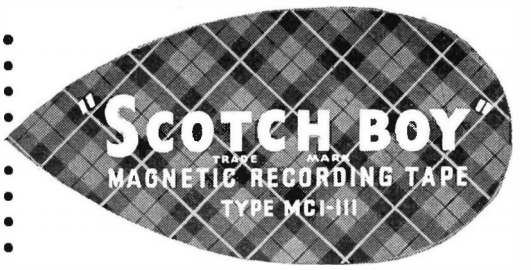

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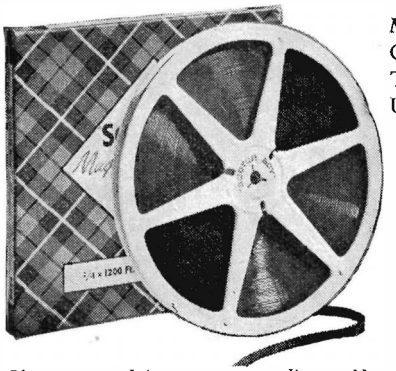

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Coercivity . . . . . 240-260 Oersteds
Total Remanent Flux . . 0.4/0.5 lines ¼in. width
Uniformity throughout a reel . . . . . ±0.5 d.b.

FREQUENCY RANGE

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

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

PLAYING TIMES (per track)

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

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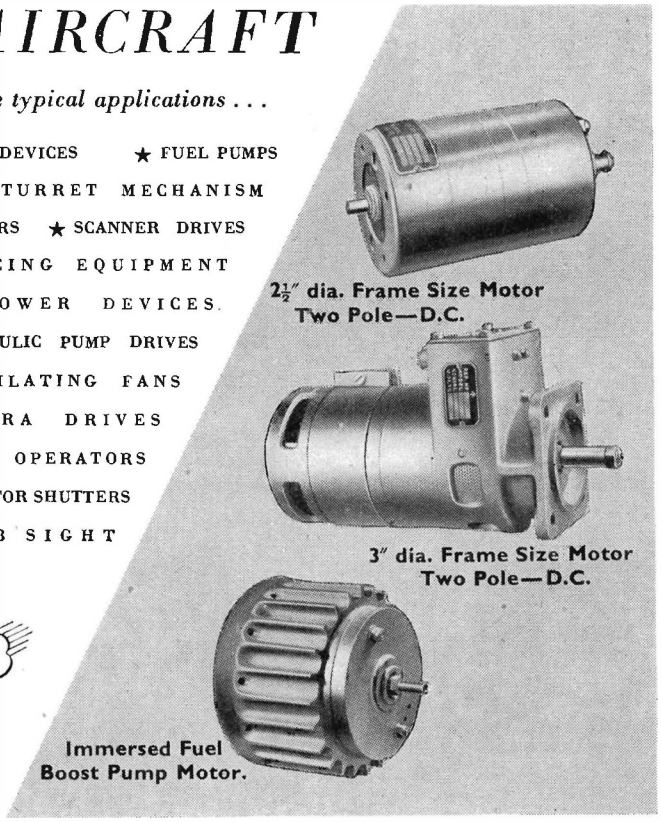

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CHARACTERISTICS AND NOMINAL DIMENSIONS

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* *Telcothene (Regd.) is polythene processed by Telcon to provide specific characteristics.*

CODE NUMBER	Z.5	Z.3	Z.1	Z.14	Z.6
Approx. overall size, ins.	5/16	5/8	1	1/2	1
Characteristic impedance, ohms.	130	330	550	1000	1900
Capacitance, mmf/ft.	55	50	50	80	45
Attenuation, db 100 ft. 1 Mc/s.	2.3	1.7	1.4	8	10
10 Mc/s.	8	6	5	30	45
100 Mc/s.	25	22	23	—	—
Velocity ratio v/c	0.14	0.06	0.036	0.014	0.012
Delay microsecs 100 ft.	0.7	1.7	2.8	7.3	8.5

TELCON RF cables

THE TELEGRAPH CONSTRUCTION & MAINTENANCE CO. LTD
Head Office: 22 Old Broad Street, London, E.C.2. *Tel:* LONdon Wall 7104
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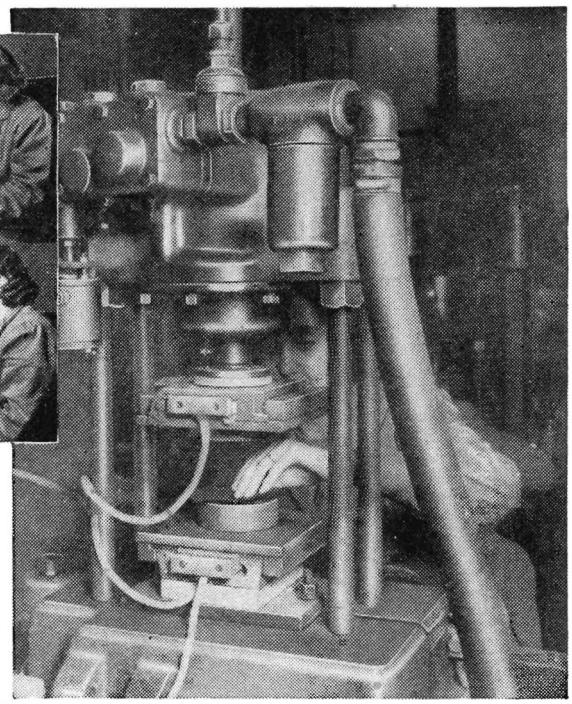
Third of a series telling the story of Goodmans Loudspeakers

" An infinite capacity for taking pains " aptly summarises the closely controlled techniques employed in the production of Goodmans speakers. Here, in the cone moulding department, the cones, on which the speaker performance ultimately depends, receive their final precision " moulding " and inspection. Moulding is just one method of treatment employed. The cones are given a special pressure treatment. They may then be resin treated, accurately trimmed to size and inspected.

Each of these processes has a profound effect on the acoustic properties of the finished speaker ; and all available scientific resources are employed to ensure a rigorous control.



(*Above*) Operating a moulding press (*Inset above*) The fundamental resonance of the cone is determined by clamping the diaphragm at its periphery and driving it by another loudspeaker. This loudspeaker is fed from a variable frequency oscillator and air-coupled to the diaphragm under test. At the fundamental resonance, a noticeable increase in amplitude of the driver diaphragm is observed. (*Inset below*) A final visual check for consistency.

AXIOM 150 Mk. II 12 in. **HIGH FIDELITY Loud-speaker**

This is the latest model in the Goodmans High Fidelity range. Bass resonance 35 c.p.s. Write for details.

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0-10 Kc/s	200,000
0-100 Kc/s	100,000
0-1 Mc/s	20,000
0-10 Mc/s	250

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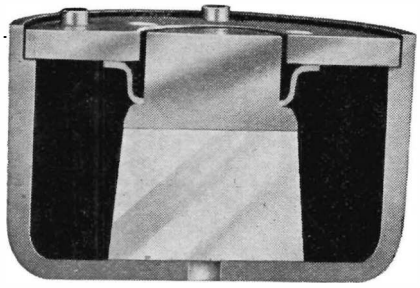

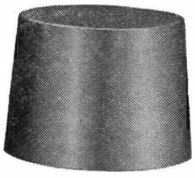

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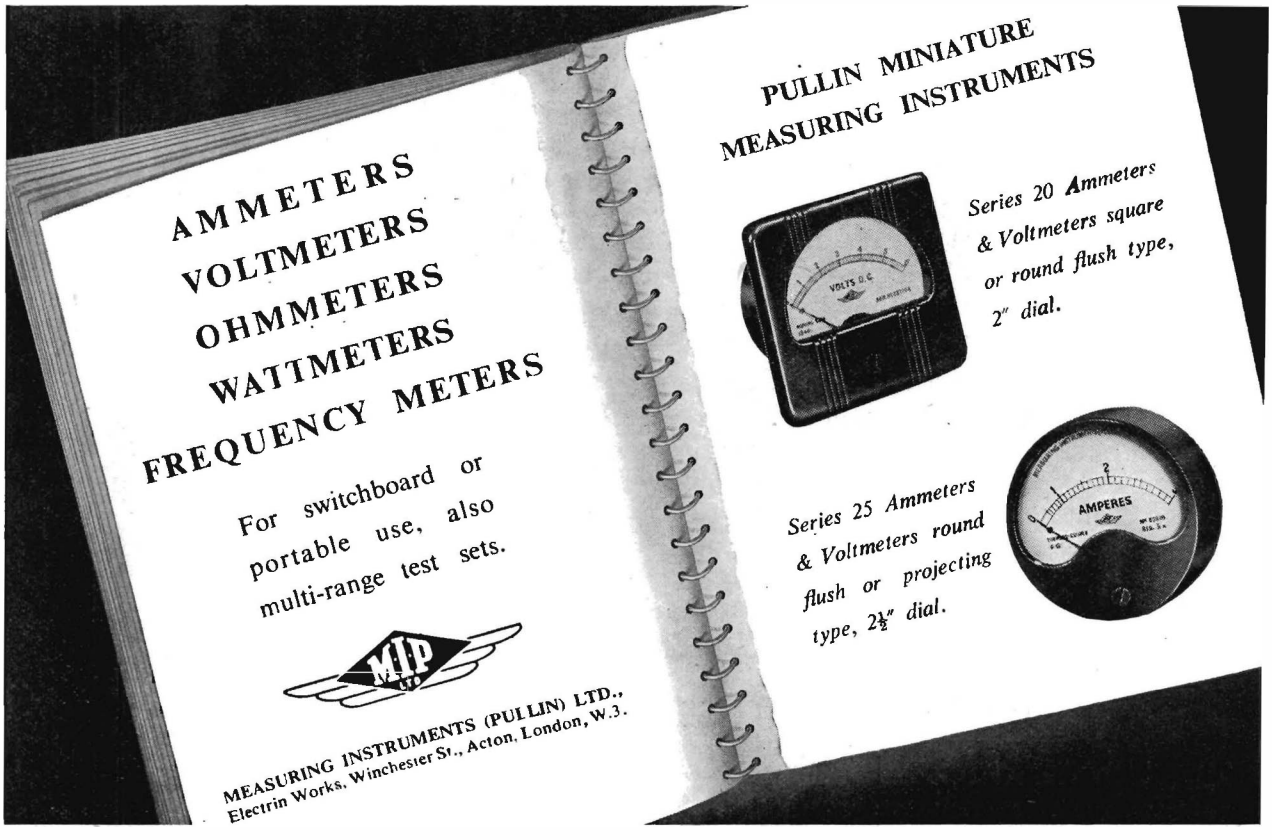

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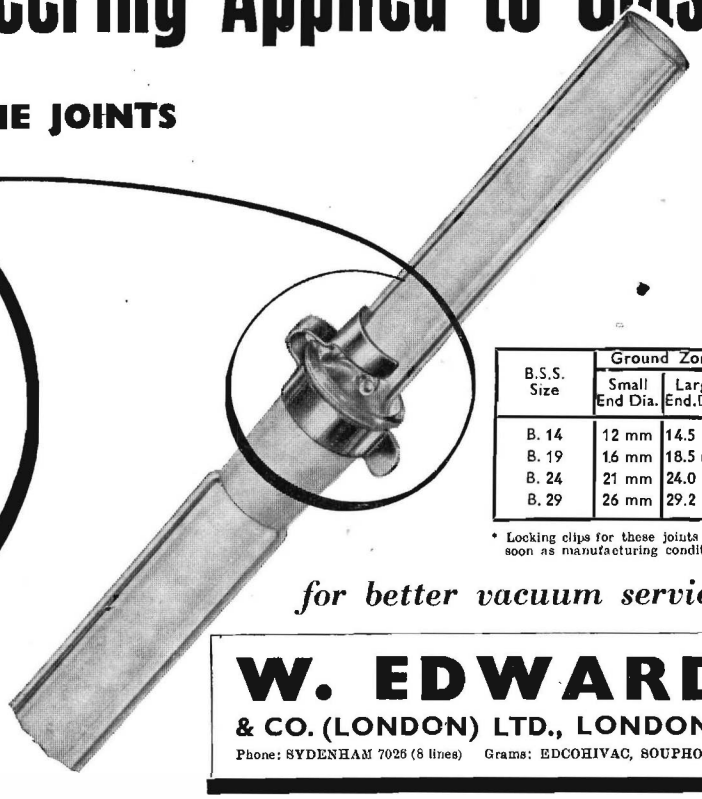

B.S.S. Size	Ground Zone		Length of Ground Zone
	Small End Dia.	Large End Dia.	
B. 14	12 mm	14.5 mm	25 mm
B. 19	16 mm	18.5 mm	*28 mm
B. 24	21 mm	24.0 mm	*30 mm
B. 29	26 mm	29.2 mm	*32 mm

* Locking clips for these joints will be available as soon as manufacturing conditions permit.

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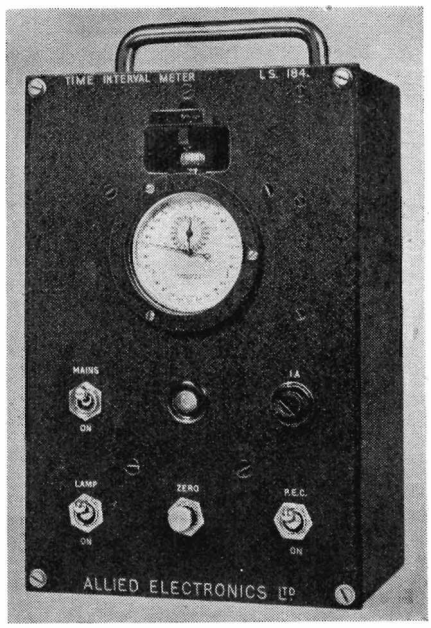

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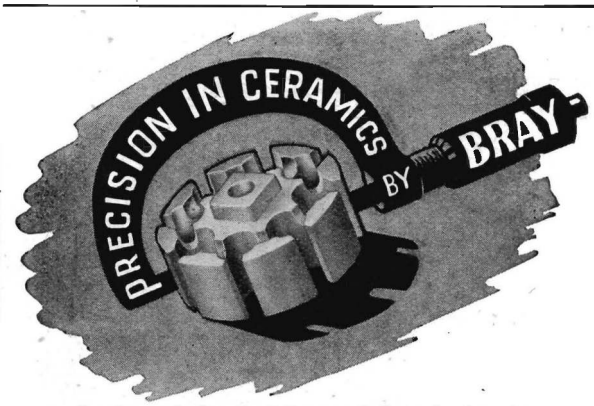

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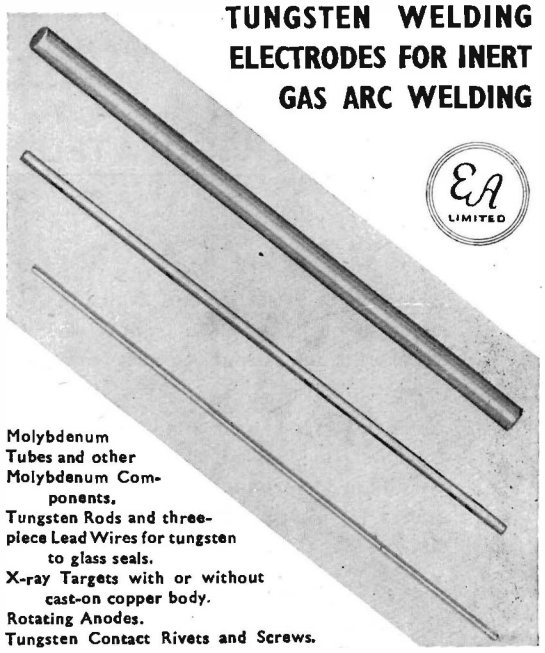

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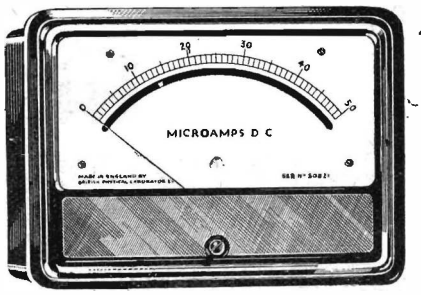

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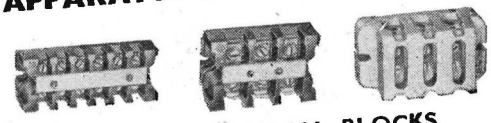

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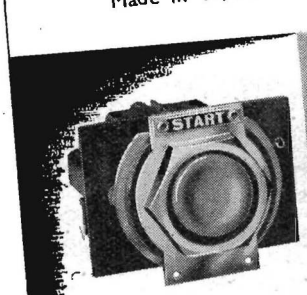

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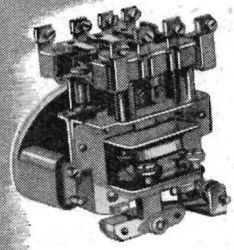

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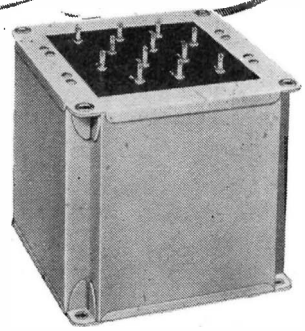

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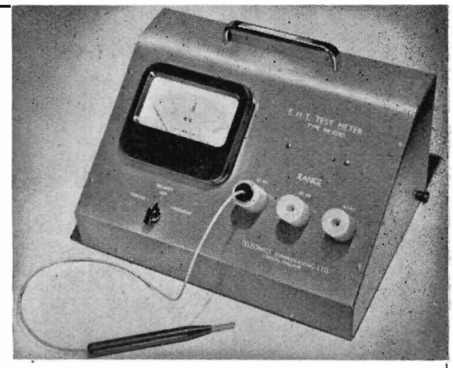

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Movement : 50 micro amps Moving Coil
Scale : 5" Linear
Accuracy : 2%

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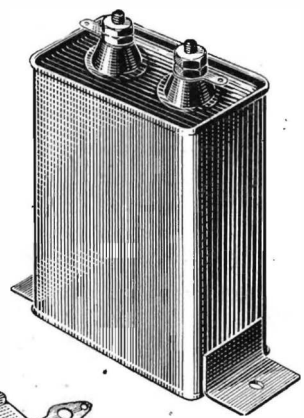

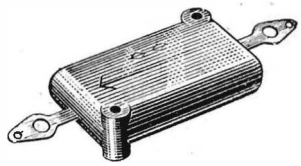

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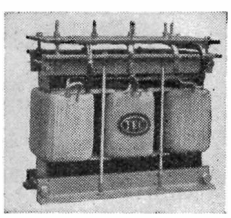

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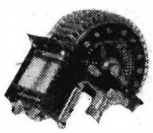

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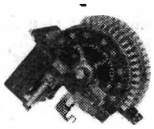

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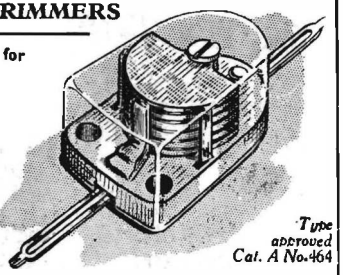

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Airmec Laboratories Ltd. 35
Allied Electronics Ltd. 48
All-Power Transformers Ltd. 49
Amos of Exeter. 54
Automatic Telephone & Electric Co., Ltd. 14
Autoset (Production) Ltd. 43

Baker Platinum Ltd. 18
Bell & Croyden, John 16
Belling & Lee Ltd. 12
Bradmatic Ltd. 54
Bray & Co., Ltd., George 50
British Insulated Callender's Cables Ltd. 51
British Manufactured Bearings Co., Ltd. .. .. .. Cover iii
British Physical Laboratories Ltd. .. 50
British Power Transformer Co., Ltd. 36
B.X. Plastics Ltd. 42

Castle Engineering Co. (Nottingham) Ltd., The 52
Chapman & Hall Ltd. 287
Cole Ltd., E.K. 5
Connolly's (Blackley) Ltd. 31
Cossor Ltd., A. C. 19

Darwin's Ltd. 47
Davis (Relays) Ltd., Jack 55
De Havilland Aircraft Co. Ltd., The 51
Derby & Co., Ltd. 53
Donovan Electrical Co., Ltd. 50

Edison Swan Electric Co., Ltd., The Covers ii and iv
Edwards & Co. (London), Ltd., W. 48
Electro-Alloys Ltd. 50
Electronic Engineering Monographs .. 55
E.M.I. Factories 37
Erg Industrial Corporation Ltd. .. 32
Erie Resistor Ltd. 26
Evershed & Vignoles Ltd. 33

Ferranti Ltd. 17
Frigidaire Division of General Motors .. 45

Garrard Engineering & Mfg. Co., Ltd., The 41
General Electric Co., Ltd., The .. 11
Goodmans Industries Ltd. 46
Griffiths, Gilbart, Lloyd & Co., Ltd. .. 43

Hifi Ltd. 55
Hivac Ltd. 53

Johnson Matthey & Co., Ltd. 3

Kempe's Engineer's Year Book 287

Linread Ltd. 20
Lyons Ltd., Claude 52

Marconi Instruments Ltd. 21
Marconi's Wireless Telegraph Co., Ltd. 30
Measuring Instruments (Pullin) Ltd. .. 47
Metropolitan-Vickers Electrical Co., Ltd. Cover i
Miltoid Ltd. 53
Minnesota Mining & Manufacturing Co. Ltd. 44
Muirhead & Co., Ltd. 22
Mullard Ltd. .. .. 28, 29 and 40
Murex Ltd. 49

Nagard Ltd. 46
N.S.F. Ltd. 34

Oxley Developments Ltd. 55

Painton & Co., Ltd. 13
Parmeko Ltd. 27
Pitman & Sons Ltd., Sir Isaac 54
Plessey Co., Ltd., The 25

Radiospares Ltd. 54
Redifon Ltd. 5
Reliance Mfg. (Southwark) Ltd. .. 54
Resinoid & Mica Products Ltd. 56
Rollet & Co., Ltd. 53
Rubber Bonders Ltd. 10

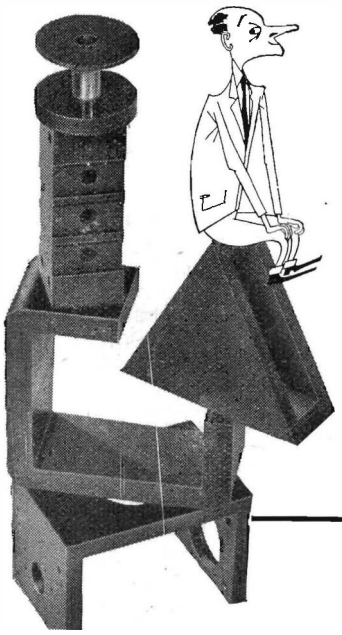
Salford Electrical Instruments Ltd. .. 41
Scott & Co., Ltd., A. C. 32
Servotronic Sales 54
Spear Engineering Co., Ltd. 55
Standard Telephones & Cables Ltd. .. 15
Stratton & Co., Ltd. 39

Taylor Tunnicliff (Refractories) Ltd. .. 23
Telegraph Construction & Maintenance Co., Ltd., The 45
Teleonics (Communications) Ltd. .. 52
Transformer & Electrical Co., Ltd., The 54
Tufnol Ltd. 7

United Insulator Ltd. 44

Vortexion Ltd. 38

Wayne-Kerr Laboratories Ltd. 40
Whiteley Electrical Co. Ltd. 29
Wiggin & Co., Ltd., Henry 42
Wilkinson, L. 55
Woden Transformer Co., Ltd. 52
Wright, Bindley & Gell Ltd. 39



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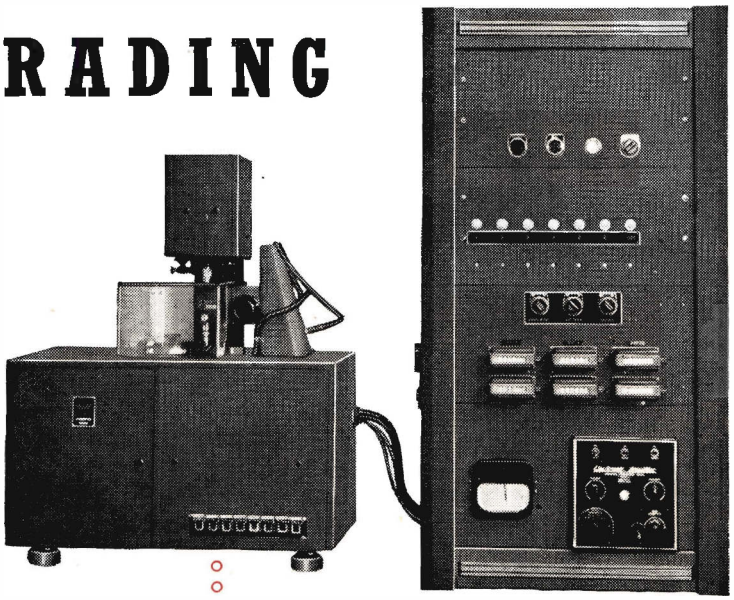

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