Electronic Engineering

JUNE 1951

TWO SHILLINGS

CLASSIFIED ANNOUNCEMENTS

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

OFFICIAL APPOINTMENTS

ADMIRALTY. Vacancies exist for Electrical and/or Mechanical Engineering Draughtsmen in Admiralty Research and Development Establishments located in the vicinity of Weymouth, Portsmouth, Teddington (Middlesex) and Baldock, Herts. Draughtsmen experienced in light current, electro-mechanical, precision mechanical and electronic equipment are particularly needed. Candidates must be British subjects of 21 years of age and upwards, who have had practical workshop experience (preferably an apprenticeship) together with Drawing Office experience. Appointments will be in an unestablished capacity, but opportunities may occur for qualified staff to compete for established posts. The salaries offered, depending on age, experience, ability and place of duty, will be within the range £320-£560 p.a. Hostel accommodation is available at some Establishments. Applications, stating age and details of technical qualifications, apprenticeship (or equivalents) Workshop and Drawing Office experience, should be sent to Admiralty (C.E.11, Room 88) Empire Hotel, Bath, quoting DM/R.D. Original testimonials should not be forwarded with application. Candidates required for interview (at London or Bath whichever is nearer) will be advised within two weeks of receipt of application. W 2780

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

BRITISH ELECTRICITY AUTHORITY London Division. Applications are invited for the following appointments : Assistant R. & M. Engineer (Mechanical)—Acton Lane Generating Station. Candidates should have had a sound engineering training—preferably an apprenticeship with a Manufacturer of heavy engineering plant. They should also have had considerable experience in the inspection, planning and supervision of the overhaul of all Power Station plant, particularly Turbines and their auxiliary equipment. Salary in accordance with revised N.J.B. Schedule, Class H, Grade 9, i.e. £693 p.a. inclusive of London Allowance. Station Shift Control Engineer—Woolwich Generating Station. Candidates should possess good technical qualifications and have had sound technical training and practical experience in the control and operation of steam generating plant and main switchgear. Salary in accordance with revised N.J.B. Schedule. Class G. Grade 10, i.e. £565 19s. p.a., inclusive of London Allowance. Boiler House Shift Charge Engineer—Hackney Generating Station. Candidates should have experience of control of boiler operation and staff. Technical knowledge of combustion is essential. Salary in accordance with revised N.J.B. Schedule, Class F, Grade 9. i.e. £564 18s. p.a., inclusive of London Allowance. All the foregoing posts are superannuable. Applications stating age, qualifications and experience should be addressed to the Divisional Secretary, British Electricity Authority, London Division, Ergon House, Horseferry Road, Westminster, S.W.1, to be received within 14 days of the appearance of this advertisement. J. N. Waite, Divisional Controller. W 2904

CITY OF BIRMINGHAM Education Committee. College of Technology, Birmingham. Department of Physics and Mathematics. Applications are invited for the following posts : Lecturer in Physics. The Department is concerned mainly with Post Graduate courses, External Degrees in Pure Science and Special Physics and National Certificates in Applied Physics. Research or industrial experience, preferably in electronics is desirable. Salary will be in accordance with the 1951 Burnham (Further Education) Scale for Lecturers (£900 x £25—£1,000 for men, £720 x £20—£800 for women). Research Assistant in Physics to work in the field of ultra high frequency electronics. Applicants should have a good Honours Degree in Physics of a University to which a thesis for a Higher Degree (M.Sc. or Ph.D.) may be submitted on the basis of research work conducted externally. Applicants should also have some knowledge of electronics. The appointment will be for two years in the first instance but may be extended to a third year. Research Assistants are required to devote some hours weekly in assisting with laboratory supervision. Salary will be in accordance with the 1951 Burnham (Further Education) Scale for Grade 'A' Assistant Teachers (Men: £375 rising by annual increments of £18 and one final increment of £21 to £630. Women: £338 rising by annual increments of £15 and one final increment of £16 to £504), plus 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 by sending a stamped addressed foolscap envelope to the Registrar, College of Technology, Suffolk Street, Birmingham, 1. Completed forms should be returned to him not later than two weeks after the appearance of this notice. C. McCaw. Clerk to the Governing Body. W 1307

MIDLANDS ELECTRICITY BOARD. Appointment of General Assistant Engineer. Applications are invited for the position of General Assistant Engineer in the Chief Engineer's Department. The successful applicant will operate from Aston Fields Depot, Bromsgrove. Applicants should have had considerable experience in the operation and maintenance of V.H.F. Radio and Radar equipment and a knowledge of maintenance of wired telecommunication equipment is also desirable. The successful applicant will be required to maintain equipment of this type installed in vehicles and fixed stations throughout the Area. The conditions of service will be in accordance with the National Joint Board Agreement and the salary, subject to negotiation, will be Schedule 'C,' Grade 8. Class AX/DX £437/£622 per annum, the commencing figure being determined according to qualifications and experience. Applications stating age, experience and qualifications should be made within 14 days to The Secretary (Ref. FWC), Midlands Electricity Board, Board Headquarters, Mucklow Hill, Halesowen, Nr. Birmingham. A Stephens. Secretary. W 2893.

THE CIVIL SERVICE COMMISSIONERS give notice than an Open Competition for pensionable appointment to the Assistant (Scientific) Class (Basic Grade) will be held during 1951. Interviews will be held throughout the year, but a closing date for the receipt of applications earlier than December 1951, may eventually be announced either for the competition as a whole or in one or more subjects. Successful candidates may expect early appointments. Candidates must be at least 17½ and under 26 years of age on 1st January 1951, with extension for regular service in H.M. Forces. but other candidates over 26 with specialised experience may be admitted. All candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects :- (i) Engineering and physical sciences. (ii) Chemistry, bio-chemistry and metallurgy, (iii) Biological Sciences. (iv) General (including geology, meterorology, 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—Men £215 (at 18) to £330 (at 25)—£455; rather less in the provinces and for women. 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 59/51. Completed application forms should be returned as soon as possible. W 2883

SITUATIONS VACANT

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

A LARGE AIRCRAFT FIRM in the Midlands has vacancies for men with experience in construction and/or maintenance of electronic equipment. Service as radio or radar technician in H.M. Forces an advantage. Vacancies also exist for men with tool room experience and some interest in electronics. Interesting work with good prospects. Apply stating age, experience, etc., to Box No. W 2911.

A VACANCY exists in a special laboratory of a well-known Company for a Telemetry Engineer. Applicants should have had good practical experience of the use of telemetry in the field. Commencing salary £500-£700 according to qualifications and experience. Please write, giving full details and quoting ref. HHE, to Box No. W 2913.

ASSISTANT ENGINEER required by large Engineering Organisation in East London area for Capacitor's design and development. 21 to 25 years of age, good opportunities for advancement. Degree or Higher National Certificate—Electrical. No previous experience necessary. Write stating age, qualifications and salary required to Box No. W 2887.

BELLING & LEE LTD., 540 Cambridge Arterial Road, Enfield, Middlesex, wish to engage a specialist to conduct aerial research and development, particularly at television frequencies. Applicants must possess scientific qualifications together with considerable experience in the field; must be imaginative and original, and able to work with minimum supervision. Excellent research facilities are available and an attractive salary will be offered to the right applicant. W 134

CROMPTON PARKINSON LIMITED invite applications from graduate Physicists or Electrical Engineers with good Honours Degrees to work in their Lamp Development Laboratory on Electric Discharge Lamps and Control Gear. Applicants with or without experience will be considered. Good prospects for man wishing to make a career in Industry. Send full particulars of training and practical experience, if any, to Ref. GLD, Crompton Parkinson Ltd., Guiseley, Nr. Leeds, Yorkshire. W 2892

DESIGN DRAUGHTSMAN (Senior) experienced in instrument design required by large light engineering company, Ilford district. Apply in writing giving age, previous experience and salary required to Box No. W 2910.

DEVELOPMENT ENGINEER required for work on textile testing instruments. Must have B.Sc. Physics Degree or equivalent qualifications. Interesting and progressive job for right man. South Manchester district. Reply giving full details of education, technical qualifications, age, and salary required. Box No. W 1297.

DEVELOPMENT ENGINEER required for interesting and progressive work in design and development of small transformers for radio equipment. Previous experience of this type of work an advantage. Salary according to age and qualifications. Apply, stating age and full details of qualifications and experience to the Personnel Department, E.M.I. Engineering Development Limited, Blyth Road, Hayes, Middlesex. W 2889

DEVELOPMENT ENGINEER 24/30, education to H.N.C. standard or higher, for old established firm of Precision Electrical Instrument Makers in S.E. area. The work is in connexion with development of industrial con-

SITUATIONS VACANT (Cont'd.)

trol devices, magslips and servo mechanisms. Applicants should have experience of light electro-mechanical apparatus and small A.C. motors, also some knowledge of electronics. Applications giving full particulars of age, experience and salary required to Box No. W 2897.

DEVELOPMENT ENGINEERS required for the Line Telephone Transmission Section. Applicants should possess Degree or equivalent qualifications. Salary according to age and experience. Apply in writing giving full particulars of education, experience and salary required. Siemens Brothers & Co. Limited, Ref. 715/21, Woolwich, S.E.18. W 2884

DIGITAL COMPUTERS: Ferranti Limited. Moston, Manchester, are engaged upon the long term development and exploitation of digital computers. This interesting work covers vacuum physics, the electronic and electrical properties of materials, computing and pulse circuit techniques, electrical and mechanical recording, electromechanical mechanisms, precision mechanical engineering and power supply equipment. In the course of this work there are occasional vacancies for senior engineers with wide experience from whom enquiries will be welcomed at any time. There are immediate vacancies for: (1) Engineers and Scientists for research and development work in the above fields. Qualifications include a good Honours Degree in Physics or Engineering, or equivalent experience. Salary according to qualifications and experience in the range £450 to £1,000 per annum. Please quote Ref. D.C.E. (2) Technical Assistants for experimental work in the above fields. Qualifications are a Degree or Higher National Certificate in Engineering, or equivalent. Salary according to age and experience in the range £350 to £650 per annum. Please quote Ref. D.C.A. The Company has a Staff Pension Scheme and will give housing assistance in special cases. Application forms from the Staff Manager, Ferranti Limited, Hollinwood, Lancs. W 2825

DRAUGHTSMEN—varied and interesting work on Electronic, Radar, and Electro-Mechanical apparatus is available in a Research Group located in West London. Applications are invited from experienced Draughtsmen who are capable of designing to RCS/1000 standards. Full details of qualifications, experience, age, salary required, etc., Box A.E. 373, Central News Limited, 17, Moorgate, London, E.C.2. W 2888

E. K. COLE, LTD. (Malmesbury Division), invite applications from Electronic Engineers for permanent posts in Development Laboratories engaged on long-term projects involving the following techniques:—(1) Pulse Generation and Transmission. (2) Servo 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, Engineers and Junior Grades. Candidates should have had at least 3 years industrial experience in the above types of work, together with educational qualifications equivalent to A.M.I.E.E. examination standard. Commencing salary and status will be commensurate with qualifications and experience. Excellent opportunities for advancement are offered with entry into a Pension Scheme after a period of service. Forms of application may be obtained from Personnel Manager, Ekco Works, Malmesbury, Wilts. W 2800

E. K. COLE, LTD., have vacancies in their Electronic Division at Malmesbury, Wilts., for senior and Intermediate Draughtsmen in the Development Drawing Office, for work on Radar, Communications, and Electronic Projects. Previous experience in this field desirable, but not essential. Apply in writing to the Personnel Manager, Ekco Works, Malmesbury, Wilts. W 2808

ELECTRICAL and Electronic Engineers required in connexion with expanding work on new projects. Applicants should have at least Higher National Certificate in Electrical Engineering, or an equivalent qualification, and experience in one or more of the following: small motors, instruments, servo-mechanisms, pulse techniques, computer circuits. Write, stating experience and qualifications, to Employment Manager, Vickers-Armstrongs, Ltd. (Aircraft Section), Weybridge. W 2861

ELECTRICAL ENGINEER—Degree or equivalent—experience on maintenance of instruments or light current circuits essential—required for work on electronic process control. Write giving details of qualifications and experience. Box No. W 2921.

ELECTRONIC ENGINEER required. Good academic qualifications and recognised apprenticeship desirable. Required for development work on control systems. Experience of D.C. amplifiers and computing devices an advantage. Apply with full details of experience and salary required to the Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middlesex. W 127

ELECTRONIC ENGINEERS (Senior or Junior) required for work on interesting new projects in our Research Division. Good academic qualifications required, or exceptional experience. Honours graduates in mathematics and physics will be considered even if they have had no previous electronic experience. Excellent pay and prospects for suitable applicants. Pension Scheme. Apply in writing with full personal details to: The Personnel Manager, Fairey Aviation Co. Ltd., Hayes, Middlesex, quoting Ref. RD/EN. W 2890

ELECTRONIC ENGINEERS required by well-known W. London manufacturers for work on the development of industrial electronic equipment. Preferably those with experience in the development of T.V. Camera and/or T.V. Film Scanning equipment. Good academic attainments not so important as sound practical development experience. Please write fully in confidence to Box No. W 2906.

ELECTRONIC/ELECTRICAL Engineer required with Degree in Physics or Telecommunication Engineering, and at least four years' experience of Radar. Apply Employment Manager, Vickers-Armstrongs Limited (Aircraft Section), Weybridge. W 2899

ELECTRONIC/ELECTRICAL Engineers required with Higher National Certificate (Electrical) and at least four years' experience of Radar. Apply Employment Manager, Vickers-Armstrongs Limited (Aircraft Section), Weybridge. W 2900

ELECTRONIC MAINTENANCE Engineer required. Applicants must have had practical experience on the maintenance of high frequency heating equipment. Pensionable staff appointment. Salary in the region of £500 per annum. Write with full details of experience, training and age to Personnel Office, Harris Lebus Limited, Finsbury Works, Ferry Lane, Tottenham, N.17. W 2920

ELECTRONIC MECHANIC required by Oil Refinery for maintenance work on Process Controllers. Applicants must have experience of automatic electronic control. Industrial experience preferable but not essential. Apply Box No. W 1283.

ELECTRO-MECHANICAL ENGINEER required Good academic qualifications and recognised apprenticeship desirable. Experience in electrical and electro-mechanical methods of computation; servo theory, and instrument design preferred. Apply with full details of experience and salary required to the Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middlesex. W 125

ENGINEER or Physicist required to take charge of section developing thermionic transmitting valves. Honours Degree in Physics or Electrical Engineering or equivalent essential. Previous experience of transmitting valves desirable. Salary according to experience and suitability. Apply: Personnel Manager, Standard Telephones & Cables Limited, Ilminster, Somerset. W 2898

ENGINEERING Draughtsmen, aged 22-28, having Ordinary or Higher National Certificate in Electrical or Mechanical Engineering, required for development work by well-known Instrument firm for factory in Guildford area. The engineering department is engaged on experimental work on aircraft electrical instruments, electronic equipment and servo systems. Interest in this type of work very desirable in view of close association between draughtsmen and engineers engaged on development projects. Write stating qualifications, experience, salary required to Box No. W 2912.

ELECTRONIC ENGINEER REQUIRED to handle 250 Kilowatt high frequency Induction Heater. Knowledge of Metallurgy and familiarity with high power Radio components essential. Please write stating age, experience and salary sought to Personnel Manager, De Havilland Propellers, Ltd., Manor Road, Hatfield, Herts. W 2789

FIRST CLASS ELECTRONIC ENGINEERS of British Nationality are invited to join a company located in country surroundings to the South West of—but close to—London. The company's operations which are on a considerable scale are solely concerned with pure research and development work in the Fields of Electronics, Electricity and intricate mechanisms. The working conditions are ideal and the scientific equipment is plentiful and of high quality. The positions offered are permanent, the salary will be generous and there is a pension scheme. The present staff of the Company are aware of this advertisement. Applications in the first place will be seen by the Managing Director only and there need be no apprehension in the mind of any intending applicant of any breach of confidence. Applications should contain full personal particulars, details of education and all positions held subsequently and should be addressed to the Box Number given and marked 'Managing Director.' W 1306

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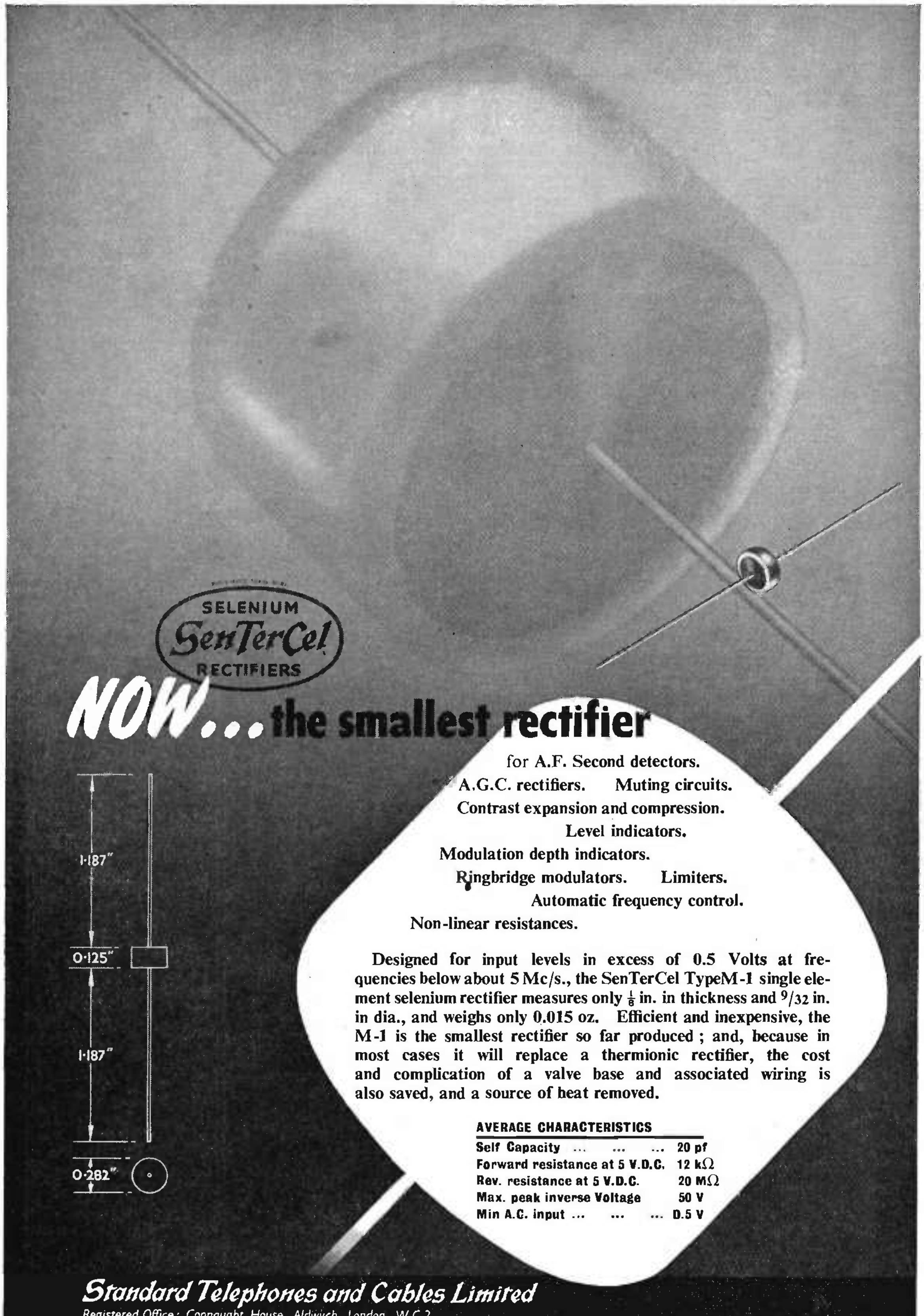
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RECTIFIERS
NOW... the smallest rectifier
for A.F. Second detectors.
A.G.C. rectifiers. Muting circuits.
Contrast expansion and compression.
Level indicators.
Modulation depth indicators.
Ringbridge modulators. Limiters.
Automatic frequency control.
Non-linear resistances.
Designed for input levels in excess of 0.5 Volts at frequencies below about 5 Mc/s., the SenTerCel TypeM-1 single element selenium rectifier measures only ⅛ in. in thickness and 9/32 in. in dia., and weighs only 0.015 oz. Efficient and inexpensive, the M-1 is the smallest rectifier so far produced; and, because in most cases it will replace a thermionic rectifier, the cost and complication of a valve base and associated wiring is also saved, and a source of heat removed.
AVERAGE CHARACTERISTICS
Self Capacity ... ... 20 pf
Forward resistance at 5 V.D.C. 12 kΩ
Rev. resistance at 5 V.D.C. 20 MΩ
Max. peak inverse Voltage 50 V
Min A.C. input ... ... 0.5 V
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Registered Office: Connaught House, Aldwych, London, W.C.2
RECTIFIER DIVISION · WARWICK ROAD, BOREHAM WOOD, HERTS Elstree 2401 · Telegrams: SenTerCel Borehamwood

ENGINEERING establishment, West London area, require several first-class Project Design Engineers for work of an intricate mechanical and electro-mechanical nature. Only qualified men capable of undertaking complete design of projects, under guidance of Chief Engineer and Chief Design Engineer, will be considered. Experience in either of the following fields will be advantageous: Printing Machinery, Automatic Feeding Apparatus, Teleprinter principles and Electronic Controls. Write in first instance giving full experience and qualifications to Chief Engineer, Box No. W 136.

ESTIMATING ENGINEER required by large radio manufacturer in East London. Applicants should be practically trained and should have experience in the preparation of detailed estimates for radio receivers. Good salary and prospects are available to a man possessing the above qualifications. Kindly state details of qualifications and experience with age and salary required to Box No. W 2886.

EXPERIENCED Instrument Assemblers required for new British precision miniature camera project, S.W. London. Interesting work, excellent conditions, attractive rates. Box No. W 2902.

FERRANTI LIMITED, Moston Works, Manchester, have staff vacancies in connexion with long term development work on an important radio tele-control project. (1) 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-£1,500 per annum. Please quote reference R.S.E. (2) Engineers and Scientists for research and development work in the following fields :—Radar, radio and electronic circuits, microwaves, 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, £420-£1,000 per annum. Please quote reference R.T.E. (3) Technical Assistants for experimental work in the fields listed in (2) above. Qualifications required: A Degree or Higher National Certificate in Electrical or Mechanical Engineering or equivalent qualifications. Salary in the range of £260-£550 according to age and experience. Please quote reference R.T.A. The Company has a Staff Pension Scheme, and will give housing assistance in special cases. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti Limited, Hollinwood, Lancs. W 2764

INSTRUMENT DRAUGHTSMAN required for design work on Electrical and Mechanical devices. Interesting work on new projects for keen man with initiative. Apply, in writing, giving details of experience and qualifications to K.D.G. Instruments Limited, Purley Way, Croydon, Surrey. W 2918

JUNIOR ENGINEER required for testing and calibrating high grade audio frequency equipment, previous experience essential. Apply giving age, full details of education, experience and salary required to E.M.I. Studios, Limited, 3 Abbey Road, N.W.8. W 1304

JUNIOR ENGINEERS interested in radio/radar and servo-mechanisms are required in special English Electric Company Laboratory working on new defence project. Preference given to applicants with Ordinary or Higher National Certificates in Electrical Engineering. Progressive position, commencing salary £400-£600 p.a. according to qualifications. Write giving full details of age, qualifications and experience and quoting ref. 815A, to Central Personnel Services, English Electric Co., Ltd., 24-30 Gillingham Street, London, S.W.1. W 2864

LABORATORY TECHNICIAN—A vacancy in a Research Laboratory, South Midlands area, for a technician to work on instrument development. A sound practical knowledge of electronics and of the general construction is essential. Apply stating salary required. Box No. W 1305.

MECHANICAL ENGINEER required. Good academic qualifications and recognised apprenticeship desirable. Preferably experienced in one or more of the following: Precision mechanical design; hydraulics or pneumatic servo systems; servo theory; aerodynamics. Apply, with full details of experience and salary required to the Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middlesex. W 129

PLANNING AND PROGRESS Engineer required by electronic engineering company manufacturing industrial electronic equipment. Must have sound experience of electronic instrument manufacture and radio or electronic components. Age 25/35 years. Reply giving full details of experience, age and salary required. Quote references to Box No. W 1298.

PRODUCTION ENGINEER to qualify as Manager of production for high-grade electronic instruments at new factory in Surrey. Must be good organiser, able to expand production by drive and initiative while maintaining quality. Excellent prospects for the right man in a new and expanding venture. Full details to Box No. W 2891.

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

QUALIFIED ELECTRONIC ENGINEER, is urgently required for the test and development departments of well known Automobile Manufacturing Company. Applicants should at least hold a H.N. Certificate Electrical Engineering and preferably a Degree, also should have had some previous experience in the practical aspects of this type of work. Salary according to age, experience and qualifications, sound prospects. Apply Box No. W 2922.

RADIO - RADAR Development Engineers urgently required, accommodation available. Applications are invited from Senior and Junior Development Engineers, preferably with experience of Radar or microwave technique, who are capable of developing equipment or components to Service Specification. Successful candidates will be employed on work of great National Importance. Write quoting reference CHC. (5) to Personnel Officer, General Electric Co. Ltd., Radio & Television Works, Spon Street, Coventry. W 2903

SALES ENGINEER for the U.K. and abroad. Must have specialized knowledge both of theory and practice of R.F. Transmission Lines and some experience in relations with the Electronic Industry and Research. Exceptional opening for right man. Fullest details of qualifications, experience, age, etc., in confidence to "S.E.F.", c/o Dixons, 1-9, Hills Place, Oxford Street, London, W.1. W 135

SENIOR DEVELOPMENT Engineers required for Carrier Telephone work in S.E. London area. Applicants should state age and details of experience and salary expected. Box No. W 2885.

SENIOR DEVELOPMENT ENGINEER. A large Engineering establishment in the North Kent area are requiring the services of Senior Development Engineers with technical and practical experience in electronics. Applicants should possess a good Degree, the minimum qualifications being the Higher National Certificate in Electrical Engineering. A good knowledge of Servo Mechanisms would be an advantage. Reply, stating age and giving full particulars of experience and salary required to Box No. W 2785.

SENIOR ENGINEER wanted for experimental work on radar, radio and/or electronics for modern high-speed project with special English Electric Company laboratory. Honours Degree preferable. Commencing salary £700/£900 p.a. Write giving full details, and quoting ref. 456D, to Central Personnel Services, English Electric Co., Ltd., 24/30 Gillingham Street, London, S.W.1. W 2869

SENIOR ENGINEER Inspectors required for Inspection work on design and development projects. The work will involve the survey and inspection of prototype and experimental models for electronic equipment. Applicants must be over 30 years of age, preferably with a Higher National or City and Guilds Final Certificate. Some general industrial experience, including electronics, essential. Apply, giving fullest details of experience and qualifications to: Personnel Department, ED/41, E.M.I. Engineering Development Limited, Hayes, Middlesex. W 1916

SENIOR AND JUNIOR Electronic Development Engineers required for work of high priority. Degree or inter-B.Sc. desirable. Salary £400-£750 p.a. according to qualification and experience. Write stating full details to Personnel Manager, The McMurdo Instrument Co., Ltd., Ashtead, Surrey. W 2907

SENIOR LABORATORY ASSISTANT. Interesting vacancy occurs in the Research and Development Section of a large Engineering Company situated in Wiltshire. Applicants should possess a good standard of education and have had previous industrial experience of Radio Components and/or moulding technique. The appointment is of a permanent nature, pension scheme in operation. Write stating full details of experience to Box No. W 2914.

STANDARD TELEPHONES & CABLES Ltd. have vacancies in their Line Transmission Division at North Woolwich, London, E.16, open to qualified Engineers and Physicists for the development of multi-channel carrier systems and microwave radio link equipment. Salary in accordance with qualifications and experience. Graduates without experience will be considered. Apply to Personnel Manager. W 2881

TECHNICAL SALES REPRESENTATIVES, one for Birmingham and the Midlands, and the other for London and the South, required by well-known component manufacturer. Applicants must be car owners and be thoroughly

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PROMINENT AIRCRAFT FIRM in Greater London area commencing new project of National importance offers unique opportunity for advancement. High salaries with monthly status and pension scheme offered to suitably qualified applicants. Engineers required with good theoretical and practical experience in design and research in any of the following specialist groups:—(a) Radar, Marine or Aircraft, (b) U.H.F. Radio, (c) Low Frequency Amplifiers, (d) Electro-mechanical measurement techniques. City & Guilds qualification or University Degree desirable though not essential. Apply stating age, nationality and experience to Box AC60194, Samson Clark & Co., Ltd., 57-61 Mortimer Street, London, W.1.

W 2790

conversant with modern radio and television technology from the manufacturing angle, and, for preference, should have had some experience in a similar capacity. Salary plus expenses. Write full details, including salary required. Box No. W 2908.

TECHNICAL SALES ENGINEER, to act as personal assistant to Sales Manager in London office of well-known component manufacturer. Applicants must be fully conversant with modern radio and television technology from the manufacturing angle, and must have had recent experience in a similar capacity. Write full details, experience and salary required. Box No. W 2909.

TECHNICAL WRITER required. A permanent interesting publicity job on communication and allied electronic instruments. Successful applicant will be required to handle press publicity and some house journal work, and should be capable of preparing news items and working up articles from bare facts. Experience in both technical and popular writing desirable. Please write giving full details, including salary required, and quoting Ref. HHH, to Box No. W 2895.

TECHNICAL WRITERS (Male or Female) required to prepare and edit reports and handbooks for publication. Qualifications: a good general training in electronics with wide practical experience of electronic equipment, marked critical faculty (form and content) and ability to write clear English. Applicants should write giving full details to: Personnel Department, ED/42, E.M.I. Engineering Development Limited, Hayes, Middlesex. W 2917

TESTERS required for work on high frequency generators for induction heating. Applied High Frequency Limited, Actarc Works, 52a, Goldhawk Road, London, W.12. Phone SHE. 1151. W 2915

THE CAMBRIDGE INSTRUMENT Co. Ltd., have a few vacancies for Test room assistants and scientific instrument assemblers. The work is interesting and offers good prospects to suitable applicants. Call or write to Cambridge Instrument Co. Ltd., Sydney Road, Muswell Hill, N.10. W 2905

THERE ARE a number of vacancies suitable for Honours Graduates in physics, electrical or mechanical engineering or mathematics or a good general Degree covering two or more of these subjects, for both research and development work in the following fields: Radio and Line Communications, Radar, Electronic Instrumentation, Microwaves, Ultrasonics, Vacuum Techniques and Electromechanical Devices. Salary according to qualifications and experience consistent with general present-day levels. There are vacancies for which considerable post-graduate experience is required and others for which previous experience is not necessary. Consideration will be given to students taking finals during the current academic year. Prospects of promotion are good and the posts all fall within the Mullard Company's Superannuation Scheme. Apply Personnel Officer, Mullard Electronic Research Laboratory, Salfords, Nr. Redhill, Surrey. W 2896

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The "Belling-Lee" page for Engineers

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WITH FLANGE

L718/S
WITH SKIRT

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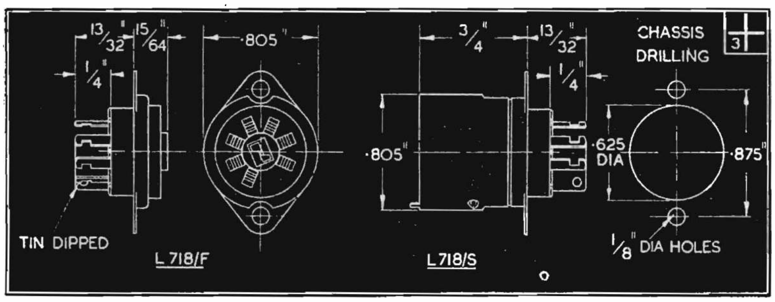

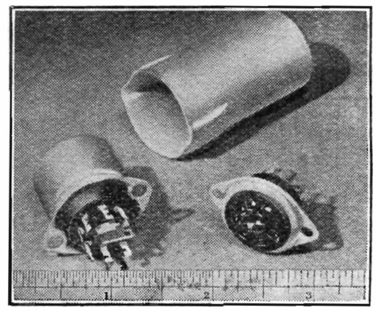

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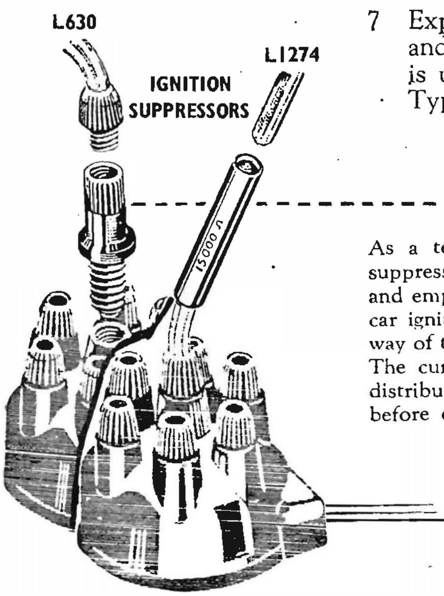
7 Experimental Inter-Services Nos. XZ.560127 for L.718/S and XZ.560132 for L.718/F have been allocated, and it is understood that the X will be dropped now as full Type Approval has been granted.



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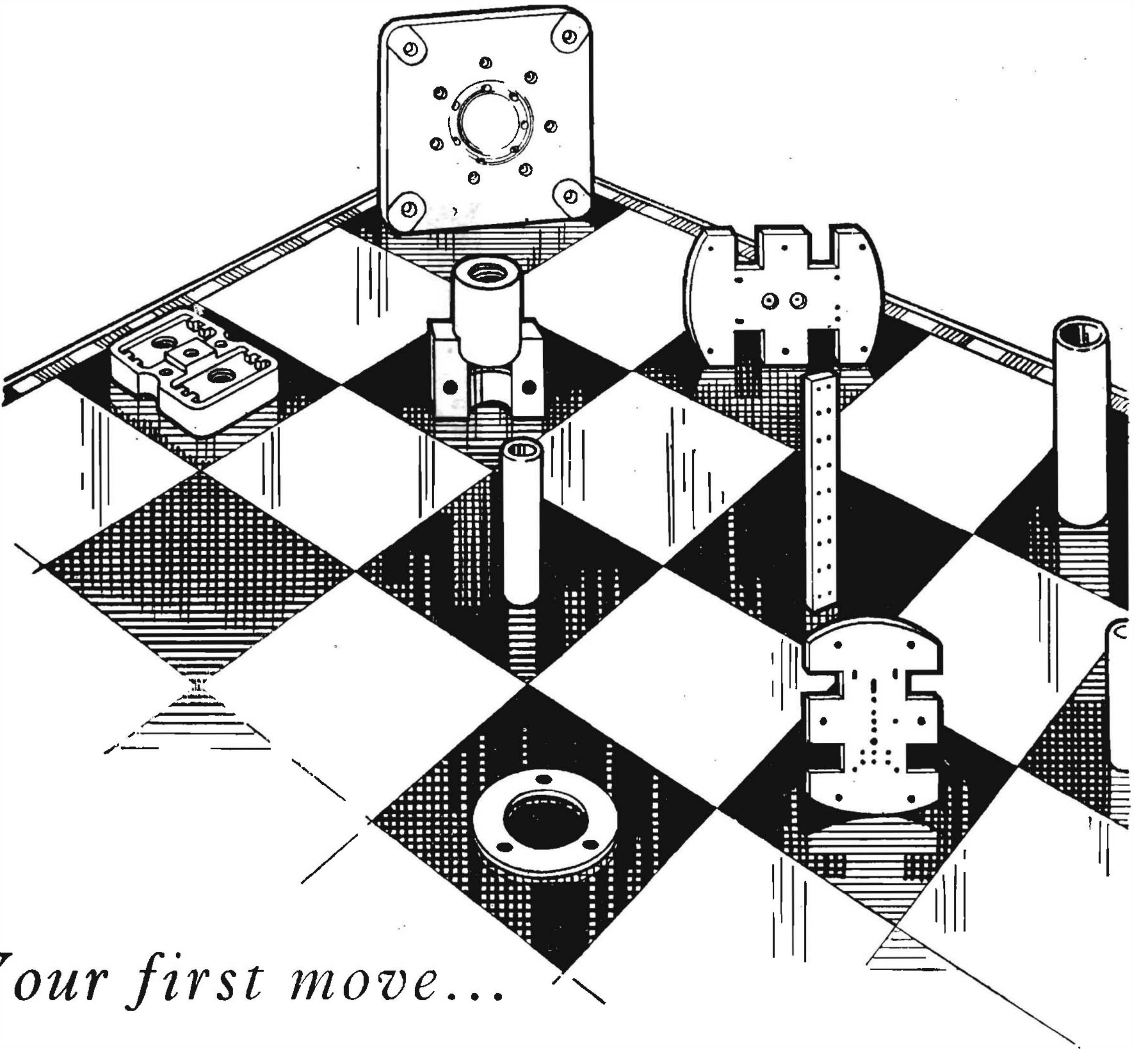

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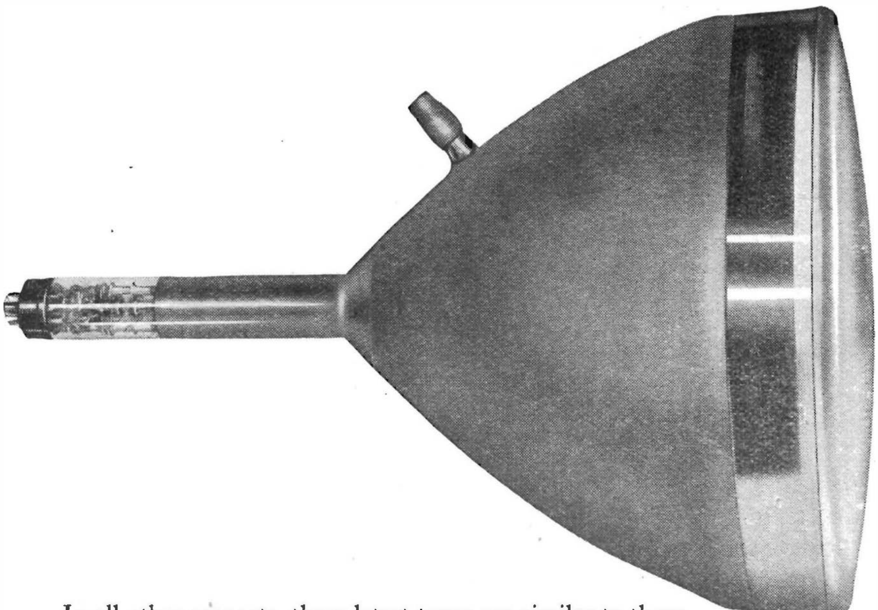

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Electronic Engineering

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

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Electronic Engineering

Vol. XXIII. JUNE 1951 No. 280.

Commentary

IN an article in this month's issue on the Golden Jubilee of the British Standards Institution, the author traces the history of standardization back as far as 2500 B.C., when the first standard units of length, volume and weight were instituted in Babylon, yet the surprising fact is that standardization on a properly organized basis has been in existence for a mere fifty years and started in the engineering industry of this country.

It seems that in 1901, a London iron and steel merchant named H. J. Shelton was the first to draw attention to the difficulties and to the waste involved in handling a large range of types and sizes of iron and steel sections, many of which differed very slightly from each other. He succeeded in securing the interest and help of Sir John Wolfe Barry, who was the President of the Institution of Civil Engineers at the time, and the outcome was the formation of an Engineering Standards Committee representing the Institution of Civil Engineers, the Institution of Mechanical Engineers, The Institution of Electrical Engineers, the Iron and Steel Institute and the Institute of Naval Architects.

The Committee proceeded very rapidly to work, and one of its first successes was the reduction of a previously unlimited variety of iron and steel sections to an ordered list of a hundred or so agreed standards which covered adequately all the requirements of the day.

Impressed by the remarkable improvements in manufacturing efficiency and by the substantial economies in production, stocking and distribution which resulted from the work of the Standards Committee, industries outside the engineering industry were stimulated to put their own house in order and to produce standards of dimension, quality and function for their products.

The overall improvement produced by intelligent standardization became so obvious, and the desire of industry for standards so strong, that the Royal Charter of the original Standards Committee was revised so that its terms of reference would embrace a wider field of productive industry.

By 1918 the Committee had become known as the British Engineering Standards Association and in 1931, after a further Royal Charter, the name of British Standards Institution was adopted.

This month the B.S.I. celebrates its Golden Jubilee and as part of the commemorative ceremonies, a special exhibition illustrating the progress in standardization made over the last fifty years is to be opened on June 18th at the Science Museum, South Kensington, and will remain open to the public for a period of twelve days.

While engineers as a whole are appreciative of the benefits of standardization, the general public is only vaguely aware of the achievements of the B.S.I. and is woefully ignorant of the general improvement in our well being. Standardization has entered so much into our daily lives that nowadays a very wide range of manufactured products is covered by specifications issued by the B.S.I. It may come as a surprise to many of us to learn that such domestic articles as the humble dust-bin and the ubiquitous milk bottle are made to standards recommended by the B.S.I.

So great is the reputation of the B.S.I. internationally that many standards of the B.S.I. are now adopted by the various countries of the Commonwealth and endorsed as their own, and an International Organization for Standardization was formed in 1946 linking the B.S.I. with some twenty-eight countries including the Dominions, the United States, France, Russia, China and the Argentine.

It is hoped, therefore that visitors to the Festival Exhibition at the Science Museum will not miss the opportunity of inspecting this commemorative display of the B.S.I.

* * *

UNDUE prominence has been given in our opinion by the daily Press to the recent case of a young child who received fatal electric shock from a television receiver.

While it was correctly stated that this was the first known fatality involving a television receiver the impression undoubtedly left in the minds of many non-technical viewers is that the television receiver is an intensely dangerous piece of apparatus to have in the house.

The facts of this unfortunate occurrence are that the child, already in contact with an electric fire, which was properly and efficiently earthed, touched the metal grille covering the loudspeaker of the TV console cabinet and received a shock and burns which were subsequently fatal. The receiver—an A.C. model—used a circuit which is general practice today, in which the primary of the mains transformer is used as an autotransformer and the receiver and loudspeaker chassis are connected to the mains, and therefore "alive" when in operation.

Subsequent investigation showed that one of the screws holding the loudspeaker to the cabinet had come in contact with the metal grille and it was suggested that this had been caused by a heavy blow.

While every sympathy will be extended to the bereaved parents, it is only right to point out that the chain of circumstances leading up to the accident were unusual. In spite of the higher operating voltage the television receiver in operation in the home is just as safe as the radio receiver, or any other well made domestic appliance but it will always be difficult to legislate for a set of circumstances such as arose in this particular case.

Automatic Circuit Checker for Television Receivers

By J. M. Silberstein, Dipl. Ing. A.M.I.E.E.*

THE problem of fault finding in television receivers is one of the most complex questions met by production planning engineers aiming at a continuous, steady and smooth flow of receivers on the production lines. The solution of this particular problem has to take into account diverse factors of which the complexity of circuit, specific requirements of mass production on assembly lines and the scarcity of skilled labour are in the foreground. A television receiver rarely has less than 20 valves, several times more than a typical radio receiver, and the difficulty of testing is particularly increased if the lay-out of the set does not allow the testing of individual parts of the circuit. This is possible if parts of the circuit such as the I.F. amplifier, time base, etc., are grouped on separate sub-assemblies; unfortunately, this is not always the case, as other considerations besides the ease of testing have to be taken into account by the designer. The use of unskilled labour for continuity checking, i.e., point-to-point wiring check to a "running list", although possible, is rather expensive and time-wasting, and requires a very high degree of concentration which limits the choice of suitable workers. From the other point of view, if no circuit check is done until proper testing and alignment has begun, a great deal of time is spent by qualified fault finders in trying to find faults on the basis of general symptoms and the faulty behaviour of a part of the TV receiver which may involve several valves. The laborious process of measuring voltages and continuity of components frequently has to be undertaken before the fault is finally located.

From such considerations has arisen the idea of an automatic circuit checker which, with no ambitions to replace any skilled human agency, could execute some simple tests and locate the faults in such a manner that a skilled worker could find the exact spot in a matter of a few minutes. If approximate values of components also be checked, in as many parts of the circuit as easily lend themselves to the check, the value of the automatic testing would be further increased.

The connexion between the automatic circuit checker and the TV receiver undergoing test must be established by using connector cords ending with plugs pushed into the valve holders. There is hardly any other solution. The use of clip leads is practically impossible because of the excessive number of connexions to be established and the difficulty of avoiding short circuits. There are always strong arguments in favour of using the same set of standard valves to test all the receivers, otherwise the discrepancies between the valves will add themselves to the differences of behaviour due to the tolerances of the components, and the limits which would have to be permitted may become so wide that actual faults may remain undetected. This only applies when the method of measuring potentials—as opposed to measuring the value of components—is adopted.

The plugging of the connectors into the valveholders and the subsequent unplugging constitutes the major part of the work to be done by the operator. Whereas the actual testing time is counted in seconds, the process of plugging in may take minutes. It becomes particularly tedious and time wasting when the valves used have pin connexions demanding special care and rather weak plugs which may be easily and frequently damaged. One possible solution lies in the use of special adaptors plugged into the valveholders during previous operations on the assembly line. In this case all connector cords may end with strong plugs of the octal type. It is obvious that the adaptors need only be used for valveholders taking B8A or similar based valves.

The positioning of the circuit checker does not give rise to any doubts. It must be situated immediately after the last mechanical assembly position on the line, i.e., next to the visual inspection position and before the valves are plugged in preparing the receiver for the alignment and proper testing operations.

Testing Method

Basically, two testing methods are possible. One consists of measuring the components, or groups of them, either by direct measurement or by comparison with standards† in a bridge circuit. As valveholders are the only points of access, fairly complex networks sometimes have to be measured and currents of diverse frequencies must be used. This method would be invaluable if the stress was laid on the checking of components to their respective tolerances. But this is hardly the case. All components are checked before they are issued from stores to the production line and the likelihood of finding values outside permissible limits is fairly small. The faults which occur in practice are mainly wrong connexions, accidental short circuits and components of a value far removed from the specified one. There is also the much less frequent case of several tolerances adding up in such a way as to exceed the total tolerance which may be based on the statistical probability of addition of errors. But that is also difficult to detect by the measurement of accessible groups of components.

The second method of testing consists of measuring the actual potentials existing when the receiver, with a set of standard valves, is switched on. The problem of individual tolerances of components ceases to arise and group tolerance, much more vital, comes into play. All parts of the circuit can be checked under actual working conditions. This uses the same method as the human fault finder. Only after voltages are checked and the existence of a wrong value established, a fault finder begins to break down the suspected part of the circuit by means of an ohmmeter or some more complicated instrument.

The comparison of the two methods of testing has been fairly widely discussed in connexion with the testing of various electrical products and it would be quite unnecessary to go into further details. The defenders of each of the two methods put emphasis on different aspects of the problem and the only result of unending discussions is the

* *Sobell Industries Limited.*

† *R. C. G. Williams, J. E. Marchall, M. G. T. Bissmire and J. W. Crawley, J.I.E.E., Vol. 94, part III, p. 20.*

agreement to disagree. In the case of the automatic circuit checker described in the present article, the synthetic method has been adopted, i.e., the measurement of potentials. This method appears quite satisfactory provided a sufficiently large number of tests is made.

The tests to be made by the automatic circuit checker can be grouped in the following classes:—

(a) D.C. tests of fairly high potentials occurring on anodes and screens of various valves.

(b) D.C. tests of low potentials occurring on cathodes of various valves, some being as low as 1 volt.

(c) A.C. tests of heater voltages made on valves in strategic positions corresponding to the way these voltages are wired on the receiver.

(d) Measurement of the amplitudes of the frame and line time bases produced in the receiver.

(e) Measurement of small portions of the circuit accessible and measurable before any alignment is done, i.e., connecting a known amplitude of intermediate frequency current, modulated with audio frequency, at the input of the detector diode and checking the A.F. voltage at the anode of the output valve, both in the vision and sound paths of the TV receiver.

(f) Checking the approximate values of components in I.F. tuned circuits by applying to them a modulated voltage of varying frequency wobbulated with a frequency deviation sufficient to cover all the spread of capacitor values within tolerances and of inductance values with two extreme positions of the magnetic core used for tuning.

If the same measuring circuit is to be used for all tests, it is obvious that all measurements must be reduced to the form of measuring D.C. potentials. Whenever A.C. potentials are subject to check, they are first converted into D.C. and only then applied to the measuring circuit.

In practical cases the tolerances of all voltages are rather high, e.g., ±10 per cent, but cases may occur when it is desirable to be able to measure to much closer tolerances. A way of measuring, therefore, had to be developed to allow for any tolerances, even as low as 1 per cent. It was felt that the proper solution of the measuring circuit must cover not only the immediate requirements of the case for which the circuit checker was developed, but must present a universal answer applicable to a variety of cases, at present far beyond the horizon.

Measurement of D.C. potentials in the automatic technique consists of finding whether the measured value lies within or outside the arbitrarily prescribed limits. The absolute value of the measurement is of no interest whatsoever. Every automatic measuring device is of necessity a "go" or "no go" machine, if it is to perform a number of measurements in rapid succession.

Bridge circuits or marginal relays are usually applied for the purpose of measuring, in the above described meaning of the term. A contact voltmeter can be used or a differential relay with two windings: the current through one winding is kept constant, the current through the other winding is proportional to the voltage to be measured. Provided the sensitivity of the relay is high enough, such a method may give quite satisfactory results.

It is necessary to overcome the difficulty of switching the contact voltmeter or the marginal relay to a different setting of the scale or of the opposing currents, respectively, for each test, which may involve some not inconsiderable complications of the circuit and expense of material and labour. Another serious disadvantage lies in the cost of the contact voltmeters and the marginal relays possessing sufficient sensitivity. It is worth noticing that a marginal relay working on a differential basis is much less sensitive than a normal relay of the same construction. If a type of relay needs for operation, say, 30 ampere turns, then each winding would have to supply 600 ampere turns to guarantee the operation at 5 per cent deviation from the normal value. This necessitates the use of extremely sensitive relays, i.e., very expensive ones, which demand skilled maintenance.

It is rather tempting to find a solution which would make it possible to utilize normal telephone relays of the P.O. type in the measuring circuit. These relays are inexpensive and of robust design. They do not require undue care in maintenance and they preserve their adjustment even when working under adverse conditions. However, to obtain a satisfactory sensitivity of operation with them is rather difficult if they are to be employed as differential relays. Most of the winding space is used for the balancing ampere turns and only a small part is left for the differential ampere turns.

The answer can be deduced from logical reasoning. If it is so wasteful to perform the subtraction in the relay itself, it has to be done outside, and only the result of the subtraction applied to the relay. This is in essence the solution of the measuring circuit as adopted in the automatic circuit checker described.

This principle is illustrated in Fig. 1. A constant voltage is included in the grid circuit of the metering valve so that the mean anode current corresponds to the centre of the rectilinear part of the I_a/E_g characteristic. The voltage to be measured is opposed by a voltage from an independent source which we shall call "comparison voltage."

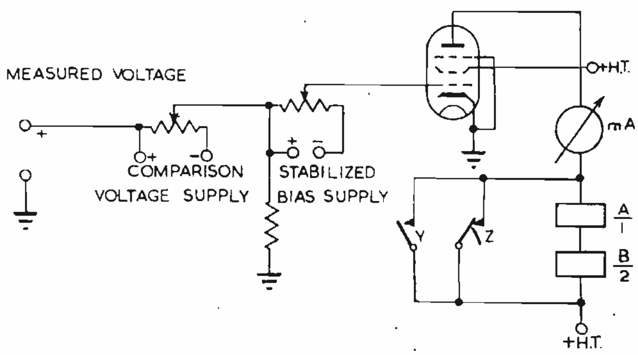


Fig. 1. Principle of the measuring circuit

The difference between the two is applied to the grid of the valve and causes a change of the anode current. There are two relays in the anode circuit of the metering valve with widely differing operating currents. Relay A works at about half the current required for relay B. If the change of anode current from the value required for the operation of relay A to the value required for relay B needs a change in grid voltage of the order of 2 volts, and the normal setting is half-way between the two values, the sensitivity of the metering circuit is of the order of 1 volt. In other words the measuring circuit treats as a fault every case when the difference between the measured and the comparison voltage is about 1 volt.

Three conditions can be created with two relays:—

(a) Relay A operates, B does not operate.

(b) Relays A and B operate.

(c) Neither relay A, nor B operates.

The fourth combination, i.e., B operating and A not operating, clearly cannot occur.

Of the three possible conditions (b) and (c) indicate a fault and (a) is a criterion for the satisfactory result of the test.

The way a test is set to a desired tolerance is clear from the above description of the principle of operation. With an intrinsic sensitivity of, say, 1 volt, a fault will be shown for a deviation from the standard value of 1 volt. Let us assume that the voltage to be checked is 250 volts. In this case a fault will be shown if the actual value differs from the nominal one by 0.4 per cent. This is clearly much too fine a tolerance for practical application. A more likely tolerance to be required is 10 per cent. To obtain this the value of the measured voltage is first reduced to 10 volts and only then opposed by the comparison voltage of 10 volts. Now, if the measured value is outside the limits of 9 and 11 volts, a fault will be shown corresponding to the tolerance of ± 10 per cent. Of course, the reduction of the measured voltage to the value determined by the intrinsic sensitivity of the measuring circuit and by the required tolerance must be performed in such a way as to ensure the proportionality of the reduced to the original value.

The measurement of very low values is treated in a similar manner. If a potential of the order of 1 volt is to be checked to a tolerance of ± 20 per cent, it is first increased five times and then opposed by a comparison voltage of 5 volts. If the measured value falls outside the limits of 0.8 and 1.2 volts, a fault will be indicated, because the increased value will be then less than 4.0 or more than 6.0 volts. Increasing the measured value to that which is necessary is rather more complicated than reducing it, but there are no inherent difficulties in achieving adequate proportionality. It could be done by means of a D.C. amplifier. The adopted method, as will be described later, consists of converting D.C. into A.C., amplifying and then rectifying it.

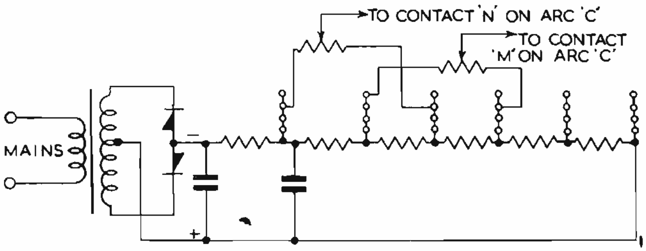


Fig. 2. Source of comparison voltage

It may appear at first sight that there is no limit to the sensitivity obtainable by the adopted method of measurement. If, e.g., a tolerance of 0.1 per cent be required, it would only be necessary to increase the measured voltage to 1,000 volts and the problem would be solved. Actually the limitations of the sensitivity are imposed by the variations of the several supply voltages. The first of these is the source of the voltage biasing the grid of the metering valve and setting the value of the anode current midway between the operating currents of the two measuring relays. If this voltage were to vary by, say, 0.2 volt, it would cause a shift of the limit and a fault in one direction would be indicated before the proper limit was reached, whereas in the other direction no fault would be indicated, although the actual values were outside the limit. For this reason the biasing voltage is derived from a neon stabilized source.

The comparison voltage (see Fig. 2) is derived from the stabilized mains supply also used for the TV set undergoing test. In this way the effect of mains variations is eliminated, as a change of the comparison voltage is accompanied by a similar change of the measured voltage. No special effort to stabilize the source of comparison voltage was made and in the circumstances it would only be harmful unless a similar stabilization were introduced in the H.T. source of the tested TV receiver. To each test corresponds a separate potentiometer, the function of which is to set the comparison voltage to the nominal value of the measured potential. To obtain a fine adjustment these potentiometers are connected across only a part (usually 20 volts) of the total source of comparison voltage.

The last remaining source, the stability of which affects to a small extent the behaviour of the measuring circuit, is the source of H.T. for the metering valve. The effect of this source is not very great and no effort was made to stabilize it, as under no conceivable conditions could a sensitivity corresponding to less than 1 per cent tolerance be required from the automatic circuit checker. Anyway, the source of H.T. is not subject to great variations as it is supplied from fairly well stabilized mains.

Switching Circuit

The number of tests to be made by the automatic circuit checker approaches 50, including a few tests checking the checker itself. The speed of testing is not of great importance, provided it is kept within reasonable limits. Plugging in and taking out the connector cords is bound to constitute the main part of the time taken by the operator. The allocation of half a second per test, i.e., 25-30 seconds for a complete testing cycle does not appear to be excessive. This leaves enough time for the actual test to be made only some time after the process of switching has been finished. Otherwise there would be the danger that the switching pulses, discharging capacitors used for some tests etc., would interfere with the test. Every test must be done under steady-state conditions.

To ensure the faultless operation of the metering relays, they must always work in the same conditions, viz., they must be released at the moment when the actual test commences. In other words, the test must consist of passing a current through the two metering relays and drawing conclusions from their behaviour. In automatic circuits this is familiarly called a "kicking" circuit. It is indispensable as the operating current is the most reliable characteristic of the telephone relay.

The checker should always start its cycle from the position corresponding to test 1. In order to be sure that this requirement is not defeated through the wrong manipulation of the operator, the checker must automatically restore itself to the same "home" position whenever the TV receiver is disconnected from the checker, even if the cycle of operations has not been completed. This may occur when there is a fault on the H.T. supply which would affect all the tests. The operator may then decide, with every justification, that the continuation of checking serves no purpose and starts withdrawing plugs without completing the cycle.

The TV receiver should not become "live" until its chassis is safely earthed. Only then should the mains be switched on and even then only for the duration of the cycle of tests. When this is completed, the mains should be automatically cut off to safeguard the unskilled operator from the consequences of her own forgetfulness.

The manipulation of the test set must be as simple as possible. Only one operating switch should be provided, both for the initial setting in motion and for the continuation of tests after a fault.

The last requirement was that only the most common types of components be used for the switching circuit, i.e., relays of the P.O. 3000 type and 25-point uniselectors. These elements have proved their reliability in the most strenuous working conditions and need very little maintenance. They should work under the conditions for which they were designed, i.e., with 50 volts supply (positive earthed) and no unusual feats of performance should be expected from them.

As there are nearly 50 tests to be performed and a rotary 25-point selector switch was to be used, the problem immediately arose whether to use one switch or two. Uniselectors with eight banks of contacts are readily available, so that there was a possibility of having eight switchable points for every test if two selectors were used. From the other point of view, to cover a multitude of tests the selector has to fulfil the function of a fairly complicated sequence switch and the wipers may not always remain connected to the same non-switchable circuit points. This rapidly diminishes the flexibility of the whole scheme. The use of two selectors, one performing the first 24 (not counting the home position) tests and the other the remaining 24 tests, introduces some complication in the circuit, far from insoluble, but nevertheless undesirable. It appears simpler to use only one uniselector with eight contact arcs and with "4 on, 4 off" arrangement of wipers and support it by additional relays for tests which would need it (one per test). In this manner simpler tests would be completely switched by the uniselector, other tests would have their individual relays switched by the uniselector when it reaches the apropriate positions, and the relays would perform the switching necessary for the test. This solution gives as an additional advantage the ease of execution of supplementary functions which may be found necessary.

Besides the two metering relays, described previously, which perform the actual measurement, the main part of the relay circuit consists of the three timing relays, X, Y, Z. They control the stepping of the selector, thus giving the rhythm of operation. They also subdivide the time available for each test, bringing various other parts of the circuit into play at the appropriate moment. The circuit of the timing relays is shown in Fig. 3. At the beginning of the period, X operates and its contacts open, thus removing the short circuit from the winding of the relay Y.

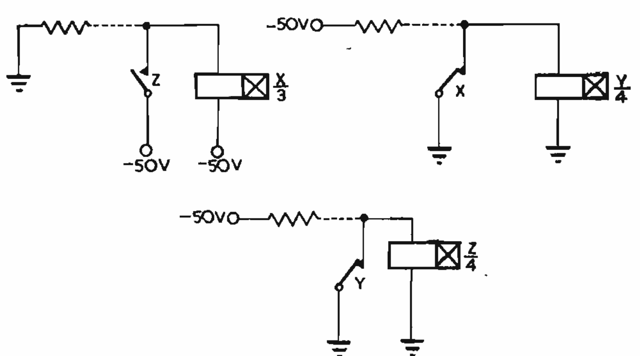


Fig. 3. Timing relays

Relay Y operates and enables relay Z to operate. But then the contacts of relay Z short circuit the winding of the relay X which duly releases. Relay Y follows suit and as a consequence relay Z also releases. All three relays are slugged so as to delay their release. The manner in which they lose current also helps to increase the delay, because short circuiting the winding of a relay enables the current caused by the back E.M.F. to flow and to prolong the period of the decay of the magnetic flux.

The total cycle of operation for the three timing relays is about half a second and is subdivided into the following intervals: —

0-20mS	All three relays released.
20-40mS	X operated, Y and Z not operated.
40-60mS	X and Y operated, Z not operated.
60-200mS	X, Y and Z operated, X in the process of releasing.
200-340mS	X released, Y and Z operated, Y in the process of releasing.
340-480mS	X and Y released, Z still operated but in the process of demagnetization. At the end of this interval Z releases and the whole chain returns to the original condition.
480mS	End of the period of one test.

The above figures are only approximately true and should not be interpreted as meaning that by an amazing feat of adjustment three absolutely identical relays have been produced. The purpose is only to demonstrate how a subdivision of time has been achieved and how each interval is clearly characterized by relay criteria.

As an example of the usefulness of the subdivision of the cycle, the actual testing circuit may serve (Fig. 1). The measuring relays A and B are normally short circuited by the springs of the relay Z. This ensures their non-operation at the moment when an actual test is to be performed. But even when the cycle starts, the relays will still remain passive, because the relay Y operates before relay Z and the "make" contacts of Y maintain the short circuit after Z has operated. This condition continues until Y has released and Z is still operated. As seen from the above described subdivision of the cycle, this would occur in the interval betwen 340 and 480 milliseconds. Whatever current flows in the anode circuit of the metering valve before the time point "340mS" is of no consequence. Thus all the initial pulses of current, discharges of capacitors, etc., have no bearing on the result of the test, which depends solely on the condition existing 340mS after the switching, by which time the steady-state condition has been reached.

Once the circuit checker has taken note of the result of the test, further steps are fairly simple. In Fig. 4 the circuit of the two test interpreting relays is clearly shown. If the test has been passed successfully, i.e., relay A is operated and relay B not operated, relay P becomes magnetized via the "make" springs of A and the "break" springs of B. Relay P maintains itself in the operating position via

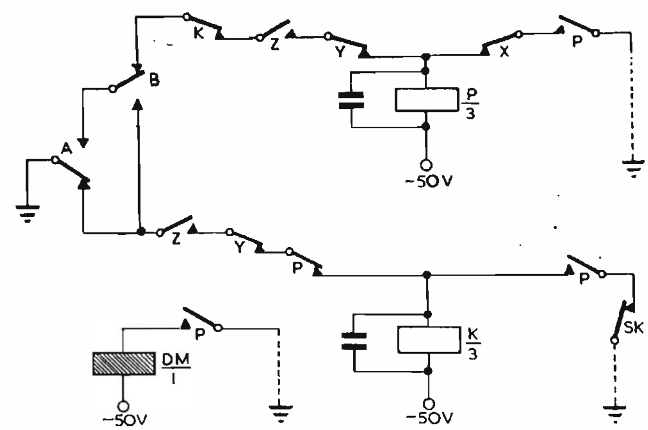


Fig. 4. Interpretat'on of the test result

its own "making" springs until the cycle ends. It connects earth to the winding of the driving electromagnet of the uniselector and thus the wipers of the selector move to the next position immediately after X operates and P has released. At this moment the next testing cycle commences.

If the test has shown the occurrence of a fault, i.e., either A and B relays operate or A and B remain not operated, relay K has its circuit closed via the "break" contacts of A or the "make" contacts of A and B. This can only happen when relay Y is not operating and Z is operating, thus preventing the operation of K before the proper time; otherwise relay K would work in the first part of the cycle before A and B have executed the test. Relay K maintains itself in the operated condition via its own "make" contacts until the switch SK is pressed by the operator. This is done after recording the number of the test. This number is seen from the lamp which is lighted when the circuit checker stops. When it moves rapidly through consecutive tests the lamps associated with the positions of the selector have no time to light, but when the selector stops the bulb lights through the numbered cap of the lamp.

Relay K having operated, the circuit checker is completely immobilized until the operator intervenes.

To avoid the difficulties associated with the marginal conditions both relays K and P have capacitors connected in shunt with their windings. It may happen that the current flowing through the windings of relays A and B is just on the limit of the operation. In such a condition a period of uncertain behaviour of one of these relays may result and pulses may be given to both K and P relays. The presence of a capacitor across the winding of the relay helps to overcome this indecision and one of the test interpreting relays operates first. Whichever has operated cuts off the other relay. It may be said that this presents a rather haphazard solution to the marginal situation, but in practice it does not matter whether a fault is shown on the actual margin or not. The fault finder will in any case be satisfied with the result of his measurement even if the tolerance is very slightly exceeded. From the other point of view, widening the tolerances would only cause the difficulty to occur at a different value of the current in the anode circuit of the metering valve and thus it would not really help. Any decision of the circuit checker is better than a prolonged period of indecision.

The circuit bringing the selector to the "home" position is presented in Fig. 5. Relay M is normally short-circuited by the "make" springs of relay N, which is operated after the switch has been pressed by the operator beginning the cycle of tests and remains operated until all connector plugs have been withdrawn from the tested TV receiver. The circuit also shows the lamps indicating the position of the selector when it stops due to a fault. The lamps are connected to every contact on one of the selector arcs, except for the "home" position.

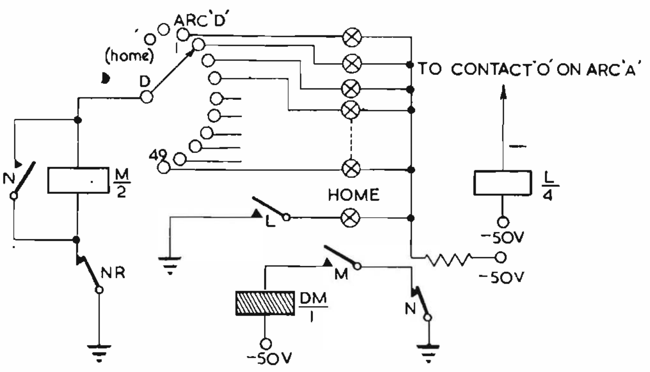


Fig. 5. Return to the "home" position

If, therefore, relay N ceases to operate because the connector plugs have been taken out and the selector is not in the "home" position, the circuit for the relay M is completed. Its active contacts connect earth to the winding of the selector-driving electromagnet, which pulls up its armature. The NR contacts associated with the electromagnet open the circuit of M which releases. At this moment the driving electromagnet releases, the wipers move to the next position and contacts NR close. If the "home" position has not yet been reached, the whole cycle of operations of M and DM starts again. In such a manner the wipers of the selector move forward until they reach the "home" contacts when relay M finally loses the source of current and so the process ends.

To the "home" contact on one of the arcs is connected relay L. The wiper of this arc is permanently connected to the wiper of another arc. On the "home" contact the latter collects earth and passes it to the former and to the relay L. "Make" springs of L light the lamp indicating that the selector is in the "home" position.

High Potential Tests

The complete method of performing the test involving the measurement of a fairly high potential, e.g., anode and screen potentials of the order of 150-250V, is illustrated in Fig. 6.

The algebraic sum of three voltages is applied to the grid of the metering valve. The first is the measured voltage reduced in value according to the required tolerance. The second is the comparison voltage, opposite in sign to the measured voltage: its potentiometer is preset to make it equal to the nominal value of the measured voltage. The third is the negative bias supply which keeps the anode current of the metering valve halfway between the operating currents of the relays A and B. If the measured voltage is greater than the comparison voltage, the anode current is greater than its nominal value and, given a sufficiently large difference of compared voltages, this current reaches a value large enough to operate relay B. If the measured voltage is smaller than the comparison voltage, the anode current becomes smaller than its nominal value. If the difference is large enough, the value of the current falls so low that relay A cannot operate. It should be remembered that the non-operation of relay A or operation of relay B are the criteria of a fault.

The process of summation of the three voltages on the grid of the metering valve is executed by the selector. The potential to be measured is brought to the corresponding contact on A arc of the selector. Wiper A is

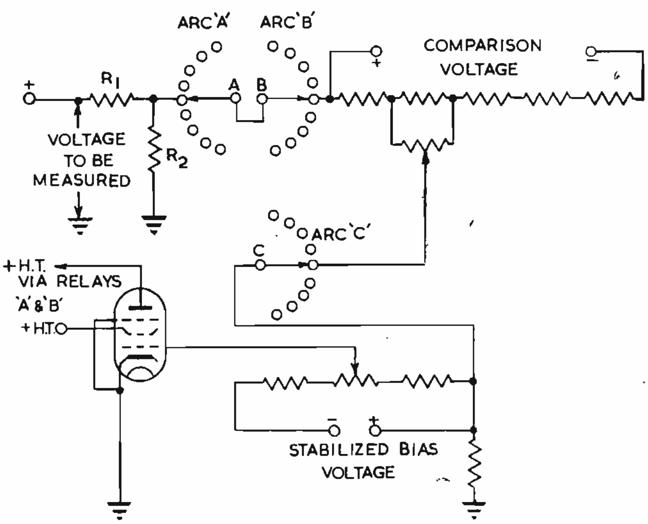


Fig. 6. Measurement of a high D.C. potential

permanently connected with wiper B. To the contact of arc B is connected the positive pole of the source of comparison voltage. The slider of the potentiometer belonging to the test being described is wired to the contact of the C arc of the selector. Wiper C is permanently connected to the positive pole of the source of bias voltage.

From the consideration of the above chain of connexions it is clear that the source of comparison voltage must have a high insulation to earth on both poles. This necessitates screening the mains transformer used for the production of comparison voltages, otherwise a high A.C. component may appear superimposed on the D.C. voltage as a result of longitudinal effects.

To avoid interference with the normal working conditions of the valves undergoing test, high values of resistors R_1 are chosen. In most cases it is about 0.5MΩ and in some cases 1MΩ. This prevents an undue drop of the measured voltages. The value of R_2 depends, for a given R_1, solely on the voltage tolerance required. It does not depend on the nominal value of the measured voltage.

Assume that the sensitivity of the metering device is 1 volt and that the deviation of the measured voltage from its nominal value V, at which the indication of a fault is to be given, is ΔV volt. The setting of the comparison voltage is such as to produce $V.\frac{R_2}{R_1 + R_2}$ corresponding to the expected nominal value of the measured voltage. If, therefore, the actual value of the measured voltage is $V + \Delta V$, the difference between the two compared voltages is $\frac{(V + \Delta V)R_2}{R_1 + R_2} - \frac{V.R_2}{R_1 + R_2} = 1$ Volt if a fault is to be indicated in the circumstances described. Solving the above equation for R_2 the formula $R_2 = \frac{R_1}{\Delta V - 1}$ is obtained.

The test described above belongs to the class not employing individual relays. As an example of the other class, the test of heater voltages will be considered.

Heater Voltage Tests

Fig. 7 shows the simplified schematic of the 50c/s receiver and of the connexions established during the test. It is worth mentioning that the same receiver is also used

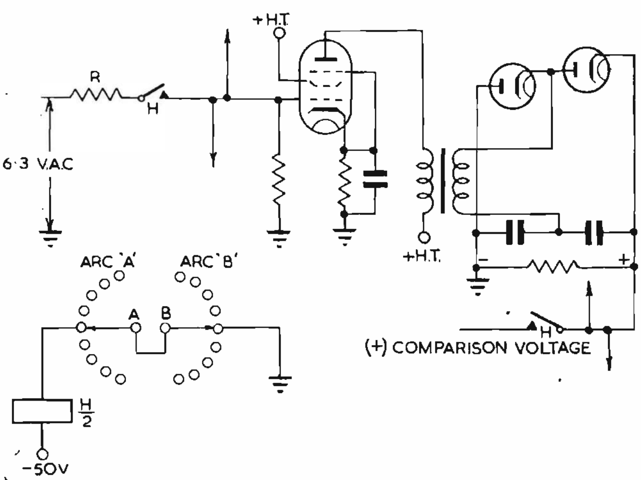


Fig. 7. Measurement of the heater voltage

as a 400c/s receiver when tests with A.F. or modulated H.F. are performed.

When the wipers of the selector reach the position corresponding to the heater voltage test, relay H operates obtaining earth through the permanently connected wipers A and B. All contacts on arc B corresponding to tests which require individual relays are earthed whereas these relays are connected to the contacts on arc A.

The operating relay H connects the measured heater voltage to the 50c/s receiver via the tolerance setting resistor R. Only one connexion is needed as the other pole of the heater source on the TV receiver is earthed.

The measured A.C. voltage is amplified first in the pentode and then rectified in the voltage doubler circuit. As extremely small powers are needed, it is not difficult to obtain in such a receiver 200 volts D.C. or more with an input of only 4 or 6 volts. In practice the tolerance expected is such that a dropping resistor must be used on the input of the receiver.

The positive pole of the rectified measured voltage is connected by means of the "make" contacts of relay H to the positive pole of the source of comparison voltage. The rest of the chain of voltages applied to the grid of the metering valve is identical with that previously described.

In this particular case the relay has only a simple function to fulfil, viz., to connect the measured voltage to the input of the 50c/s receiver and to connect the output of the receiver to the grid chain of voltages. In some cases the functions of the individual relay are more complex; three, four or even five sets of springs are used on some relays associated with individual tests.

Low Potential Tests

The measurement of small D.C. voltages, i.e., cathode bias voltage, of various valves presents a separate problem. The limits allowed are in most cases appreciably narrower than the sensitivity of the metering circuit. The way to solve this difficulty is illustrated in Fig. 8.

The cathode voltage test circuit consists essentially of three parts. An oscillator, of the R-C type, produces a 400c/s voltage which is applied via a buffer stage to a small rectifier. Any frequency could have been used, but a 400c/s oscillator had to be provided for other tests.

The impedance of the rectifier varies with the direct current flowing through it. During the test the cathode of the measured valve is connected, via a protecting and sensitivity-setting resistor, to one pole of the rectifier, the other pole being earthed. The protective resistor is large enough to prevent any appreciable change in the valve bias due to the test. As the resistance of the rectifier is much smaller than that of the resistor, the current flowing through the rectifier is nearly proportional to the voltage applied, i.e., being measured. The 400c/s voltage is also applied to the rectifier via a fairly large resistor. The A.C. voltage on the rectifier is therefore roughly proportional to the D.C. resistance of the rectifier. The 400c/s current flowing through the rectifier is much smaller than the direct current, so that the latter has complete control of the impedance.

The A.C. voltage is tapped off the rectifier, amplified in a two stage (double triode valve) amplifier and then rectified in a voltage doubler circuit. The positive pole of the D.C. source, so obtained, is connected to the positive pole of the source of comparison voltage by the "make" springs of the relay associated with this test and the usual chain of voltages applied to the grid of the metering valve is formed.

By such means the original D.C. voltage, of, say, 1 volt, may be brought up to any level required according to the tolerance desired. When the circuit is not in use, i.e., in the intervals between the cathode tests, the rectifier is left without D.C. bias and a large D.C. voltage is built up on the capacitors in the voltage doubler circuit. Thus during the actual test, when the impedance of the rectifier decreases, the capacitors discharge from the previous value, dependent on the resistance of the rectifier around zero point to the new value related to the measured voltage. This change is made smaller than the absolute value of the voltage obtained during the test. The process, therefore, takes less time than it would if the capacitors were charged from zero. The circuit is thus brought to a steady-state condition well before the actual measurement takes place.

The relay governing the test switches the cathode of the measured valve to the rectifier. In some cases when the results may be affected by possible instability, the relay also fulfils other functions preventing the instability. The instability mentioned may occur with some settings of the tuned circuits, as the circuit checker is used before any alignment functions are performed.

The D.C. resistance of the rectifier is not, as a rule, linear with the current. The nominal setting of the comparison voltage for a cathode test can not therefore correspond to the nominal value of the cathode bias voltage. It must be fixed half-way between the readings obtained at the extreme permitted values of the cathode bias. In other words, if the nominal value of the cathode bias is, say, 1 volt and the allowed limits are 0.7 and 1.3 volts, the first action is to bring the sensitivity of the circuit to a condition in which the fault will be indicated just below 0.7 and just above 1.3 volts. The setting of the comparison voltage potentiometer must be such that the current in the anode circuit of the metering valve is brought down to the

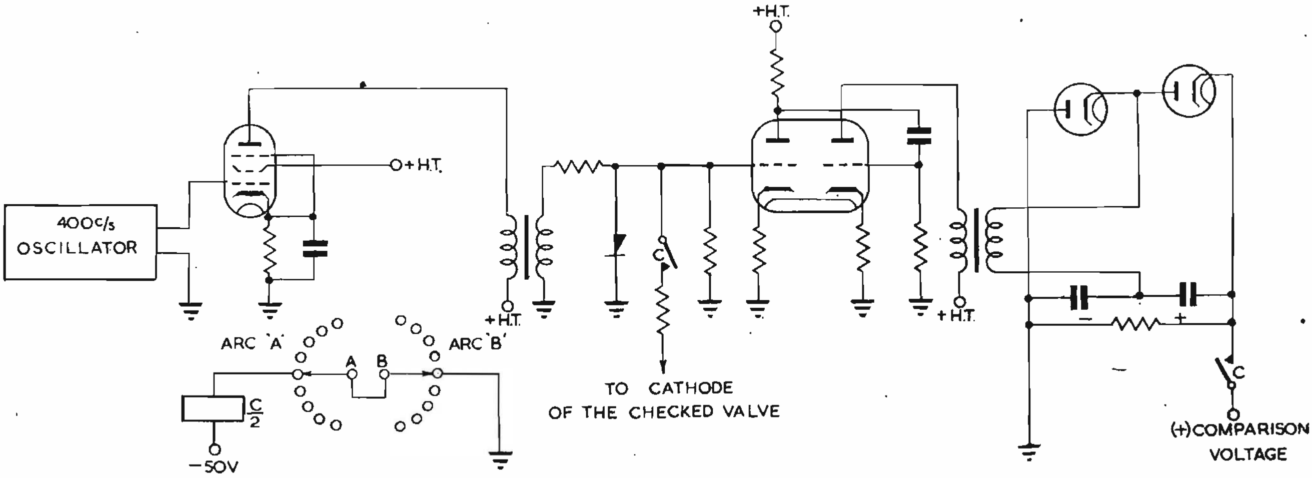


Fig. 8. Measurement of a low D.C. potential

non-operating value of relay A when the measured voltage is 1.3 volt, and to the operating value of relay B when the measured voltage is 0.7 volt. This will correspond not to the value of the metering current obtained when the measured voltage is exactly 1.0 volt, but to a higher value.

General Description of the Checker

As was mentioned in the introduction, all TV receivers are checked with a set of standard valves constituting a part of the automatic circuit checker. Their filament heating is derived from the circuit checker so that no time is lost while they warm up. The valves belonging to the H.F. part of the receiver are placed in the receiver end of the connector cords close to the connector plugs so as to preserve the shortest possible connexions between the valves and the valveholders in the TV receiver. This precaution was deemed unnecessary in the case of all A.F. and time base valves which are therefore accommodated inside the circuit checker.

The circuit checker is built in the shape of a rectangular box standing on the floor. Its upper lid is flush with the top of the operator's table on which is laid the tested receiver. The connector plugs are arranged in a row along the edge of the table. Their order corresponds to the positions of the valveholders on the TV chassis; this facilitates the manipulations and prevents mistakes. The switch used for starting the cycle tests and for restarting after a fault has been recorded is a rugged pedal switch, leaving both hands of the operator free.

The fault indicating lamps are mounted in the top lid of the circuit checker and the numbers are shown through semi-transparent labels over the lamps. In the top lid is also mounted the milliammeter reading the current in the anode circuit of the metering valve.

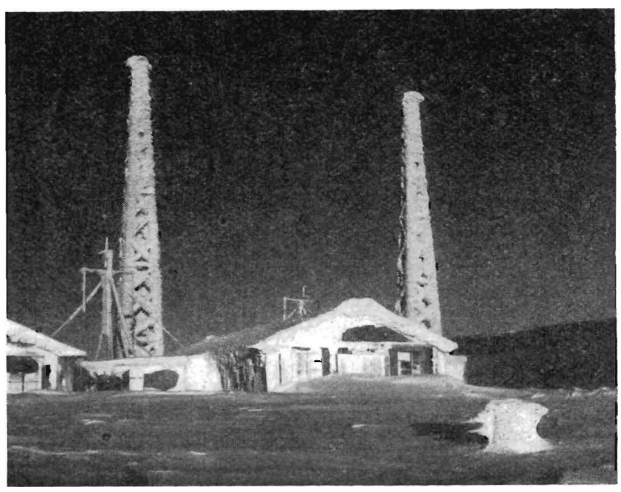
The function of the operator consists of plugging the connector cords into the appropriate valveholders of the TV receiver, connecting the mains leads to a safely protected mains box mounted on the table and then pressing the pedal switch. When the checker stops on a test, the operator writes down the number of the test and presses the switch again. When the home lamp lights up, the operator begins to withdraw the connector plugs and having done so attaches the list of faults to the set and passes it to the faultfinder.

The fault-finders are provided with the code list of the tests containing also the nominal values, e.g., 19-V9, pin 2, anode 230±20 volts. The location of the fault is usually a matter of minutes as the circuit checker has already narrowed down the field of possible errors.

Acknowledgments

The author wishes to express his thanks to Sobell Industries Limited for permission to publish the description of the circuit checker developed in their laboratories and to Mr. K. A. Braybrooks for valuable help both in developing the checker and in writing this article.

Winter at Great Dunn Fell



The illustration above shows an unusually heavy ice formation on the 120 ft. wooden towers of one of the Ministry of Civil Aviation Stations at Great Dunn Fell, Cumberland, during the severe winter earlier this year.

The V.H.F. Area Coverage Network was described by D. P. Taylor in the March issue of "Electronic Engineering" and The Great Dunn Fell station located on a site 2,780 ft. above sea level forms part of the network covering the Northern part of England. The stations in the Area Coverage Network are manned continuously and it is worthy of record that although nothing could be done to remove the great weight of ice from the towers, the Great Fell Station remained continuously in operation.

A view of the wooden towers and aerials of a similar station at Butser, Hants., was shown on page 90 of the March issue.

(Photo by courtesy of D. C. Davies, Ministry of Civil Aviation)

STANDARDIZATION

Golden Jubilee of The British Standards Institution

By R. Neumann, Dipl.Ing., A.M.Mech.E.

The British Standards Institution, whose coat of arms is shown above, celebrates its Golden Jubilee from 18-24 June. This article deals with some aspects of Standardization in general and particularly with the work of the B.S.I. since its conception. A few words are said about this work as regards the special interests of the Electronic Engineer

In his James Clayton Lecture delivered before the Institution of Mechanical Engineers in November 1950 Mr. C. G. A Rosen. an eminent American engineer, gave a quotation from A. J. Toynbee's "A Study of History." The words quoted were: "As differentiation is the mark of growth, so standardization is the mark of disintegration." This appears to be a rather sweeping statement and it may be doubted whether one should accept such an apparently disparaging remark on standardization without finding out in what context it was made.

The quotation is rather condensed, so that its correct meaning is somewhat blurred. What Toynbee actually said was: "We have seen that in the process of growth the several growing civilizations become increasingly differentiated from one another. We shall now find, conversely, that the qualitative effect of the disintegration process is standardization." And by standardization the author means the "tendency towards uniformity . . . in the history of disintegrating civilizations." But that is something different from the industrial standardization with which we are dealing here and for which a brief definition will be given later.

It may certainly be admitted that standardization, if carried too far, or if begun at an unsuitable time, or if considered as an end in itself, may prove harmful to progress. But this holds true for many other human activities. On the other hand there can be no doubt that standardization reasonably applied is very well suited for promoting progress and that without it all kinds of inconveniences may arise.

Standardization in its wider sense goes back to very early historical times. About 2500 B.C. there were already standard units of length, volume and weight at Babylon. Such standards were made legal by coded law, probably already in Hammurabi's times about 2000 B.C., but certainly in the Mosaic law, where the use of correct weight and measure is repeatedly stressed.

But taken in its widest sense standardization may even be traced back into prehistoric times. To quote P. G. Agnew's contribution to the Encyclopedia Britannica 1947: "Language is the most important example of standardization that man has brought about. Words are sounds whose meanings have become standardized and so form our principal means of communication." And such development is still going on, as may be seen from the many glossaries and definitions contained in the modern work of standardization associations of the various countries and of international bodies like the International Electrotechnical Commission (IEC), the International Commission on Illumination (CIE), the International Organisation for Standardization (ISO) and the International Consultative Committee on Telephony (CCIT).

It is customary to distinguish four phases of standardization, viz., that accomplished by individual companies, the group standards developed by trade associations and government bureaux, the standardization performed on a national scale and finally that performed on an international scale. But there is one kind of standardization which is at the same time perhaps the most widely spread and the most varied in its different forms and in the manner in which it is adhered to. It is the way in which every individual "standardizes" his own life, his order of work, recreation and sleep, the food and drink he consumes, the times he catches his bus or train for going to and from work, etc. And not only the bread winner finds that he can improve his efficiency by organizing in some convenient way his daily work, but also the housewife performs her multifarious duties in a certain more or less rigid order, as one can see from the freshly washed linen fluttering in so many back gardens every Monday morning. But this is mentioned here only in passing and we shall confine ourselves in the following to industrial standardization, and especially to that of the third phase mentioned. The first two phases and the last one will only briefly be dealt with.

As was mentioned above, the standardization of measuring and weighing units was one of the earliest steps. This is now usually the concern of state legislation. In Great Britain, for instance, the weights and measures were provided for the whole kingdom by the Sheriffs of London at the time of Richard I. At the present time we have the Weights and Measures Act of 1878; and the Standards Department of the Board of Trade is the Government Department responsible for weights and measures.

Rudimentary forms of standardization may be found, e.g., in Frontinus' description of the water supply of ancient Rome, where, as was recently shown, even the use of what is called to-day "preferred numbers" may be discerned, and in the strict codes of the guilds in the middle ages—the Hallmarks for gold and silver goods were started about in 1300 A.D. The Birmingham Wire Gauge" introduced early in the 18th century is still used to some extent on the Continent and in the U.S.A., though it was about in 1300 A.D. The Birmingham Wire Gauge with which it is frequently confounded. But industrial standardization in its modern sense was started only after the beginning of the industrial revolution, initiated by the replacement of older power sources by the steam engine. Some landmarks in this development were for instance the introduction by Eli Whitney of division of labour and of standardized parts in his rifle factory in the early decades of the 19th century in U.S.A.; the proposal of a uniform system of screw threads by Sir Joseph Whitworth in 1841; the standardization of electrical units starting in 1863 by a committee of the British Association with the "B.A. unit" of electrical resistance and then continued by the

International Congress of Electricians, Paris 1884 and Chicago 1893. Further examples are the "Deutsche Normalprofile" (standards for structural steel) 1879/80, the "Normformate" of Portsmann which standardized the paper sizes on a rational basis and have been universally adopted not only in Germany but also in a considerable number of other countries.

These examples, the number of which might be considerably increased, belong to the second, third and fourth phases mentioned above. A recent discourse dealing mainly with the first phase without neglecting the other three phases is contained in the papers read before the I.E.E. by J. T. Moore and P. J. Daglish which refer especially to electrical power engineering.

There exists a rather extensive literature on standardization and related subjects in monographs, e.g., by J. Gaillard (U.S.A.), N. F. Harriman (U.S.A.), F. Porstmann (Germany), as well as in technical periodicals in general, and there is also quite a number of journals dealing exclusively with these fields, as for instance the "Standards Review" published in irregular intervals since 1944 by the B.S.I., the monthly "Industrial Standardization" published in U.S.A., etc. Quite recently some important special reports have been published, e.g., the productivity reports "Simplification in Industry" and "Simplification in British Industry," both prepared by the Anglo-American Council on Productivity," the "Lemon Report" (1949) of the Ministry of Supply and the "Cunliffe Report" (1950) of the Board of Trade. While the Lemon Report deals generally with the standardization of engineering products and especially with the question of simplification in industry, the Cunliffe Report has as its object an inquiry into the organization and constitution of the British Standards Institution. Much useful information will also be found in the late Percy Good's Presidential Address to the I.E.E. in 1947 "The History and Philosophy of Standardization."

There is no lack of many-worded definitions of the expressions "standards," "standardization," "simplification," "specialization" and the like. For our purpose it may be convenient to use the comparatively simple definitions contained in the "Productivity Reports" mentioned above. Thus we speak of a:

"Standard" as a definition with reference to performance, quality, composition, dimensions or method of manufacture or testing; of

"Standardization" as the process of organizing agreement on (I) a standard for a particular product, range of products. or procedure and (II) the application of that standard; of

"Simplification" as the process of reducing the number of types and varieties of products made; and of

"Specialization" as the devoting of particular productive resources exclusively to the manufacture of a narrow range of products.

We are here mainly concerned with standards and standardization, while simplification and specialization, although of great importance in raising productivity, will only be considered here as activities for which the existence of standards and standardization are usual though not indispensible prerequisites. But of course it must not be forgotten that one of the main purposes of standardization, as expressed in the Royal Charter granted to the B.S.I., is the simplification of engineering and industrial materials, so that national waste of time and material may be eliminated as far as possible.

We shall now deal in greater detail with the third phase of standardization, i.e., that on a national scale, and especially with the work of the British Standards Institution which this month celebrates its fiftieth anniversary.

The B.S.I. is a national organization, the object of which is to promulgate British standard methods of tests, definitions, codes of practice and specifications for all kinds of materials, basic and intermediate, and of manufactured goods, articles and the like. While standardization in its first and second phases is much older, the B.S.I. is the oldest national standardizing body, while the corresponding bodies in U.S.A. and Germany were formed during the first world war and in France between the two wars. There are now 35 countries having national standards bodies.

The B.S.I. originated in 1901 as the Engineering Standards Committee of the Institution of Civil Engineers. This committee was primarily formed for the standardization of steel sections. The main committee consisted of representatives of the professional institutions interested in its activities, e.g., the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Naval Architects, the Iron and Steel Institute, and later the Institution of Electrical Engineers. Still later, as the scope of the work undertaken by the committee widened, other bodies came to be represented. In 1918 the Committee changed its name to British Engineering Standards Association and afterwards extended its activities to the building industry and the chemical industry. In 1929 and 1931 an original and a supplemental Royal Charter were granted to the Association and in 1931 the name British Standards Institution was adopted.

The present structure of the B.S.I. committee system is characterized by a General Council which branches out, besides to an Executive and Finance Committee, to four "Divisional Councils," one each for the building, the chemical, the engineering and the textile industry. Under these Divisional Councils work the "Industry Standards Committees" of which there are at present 10, 19, 19 and 5 respectively for the Divisional Councils mentioned. The more detailed work is carried out by the "Technical and Subcommittees" which at present number 195, 257, 1131 and 12, respectively.

As an example the 19 Industry Standards Committees under the Engineering Divisional Council are concerned with aircraft, agricultural machinery, automobile industry, chemical engineering, cinematography, colliery requisites, electrical engineering, gas, illumination, iron and steel, mechanical engineering, non-ferrous metals, petroleum equipment, refrigeration, refractory products, road engineering, scientific instruments, solid fuel and welding.

The Technical Committees are formed by representatives of those bodies which are interested in a particular subject. Their membership varies between 5 and 35. A chairman is appointed and the technical committee usually sets up a drafting sub-committee responsible for the drafting of a specification. The Technical Committees receive their terms of reference from the Industry Standards Committee under which they are formed.

The Industry Standards Committees control the work of the Technical Committees and approve the final drafts of the specifications. They also decide questions of priorities.

The four Divisional Councils co-ordinate the work of the Industry Standards Committees and are themselves responsible to the General Council. This was composed in 1949 of 68 members including, besides its own chairman and the chairman of the Finance Committee, the four chairmen and nine members each of the Divisional Councils, 17 nominees of various Government Departments, three co-opted members of the nationalized industries and one nominee each of six special bodies, among them the Federation of British Industries and the Trades Union Congress.

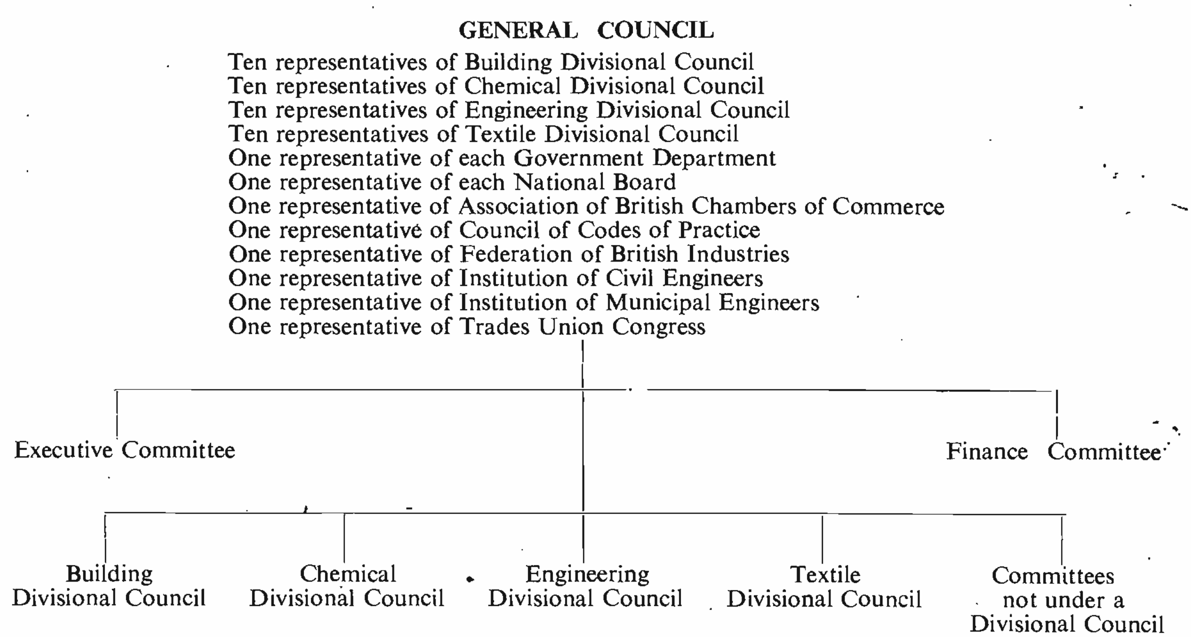
A distinction must be made between the B.S.I. committee system and the internal organization of the B.S.I. This consisted, when the Cunliffe Report was made, of the director and secretary, a technical director, six assistant technical directors, an office manager, a public relations officer, a publications officer, a sales manager, a librarian, an accountant, 26 committee secretaries, 11 other executive staff and nearly 200 clerical staff. The committee secretaries call the meetings, send out questionnaires to the industry, take minutes of the meetings. assist in drafting specifications, circulate these, assemble the comments, consult if necessary trade associations, professional bodies, etc., and after authorization arrange the publication of the specifications.

Their work is supervised by one of the assistant technical directors who act as secretary to the Industry Standards Committees and participate in the management of the Institution as members of the Director's Committee.

The technical director co-ordinates their work, acts as secretary to the Divisional Councils and is responsible for the general development of technical work. The directors and senior staff members form the Director's Committee for carrying out the day-to-day administration.

There are some basic principles governing the work of the B.S.I. First of all the standards must be in accordance with the needs of industry and fulfil a generally recognized want. The interest of both producer and consumer must be considered; and the standards must be periodically reviewed and revised if necessary. Thus the initiative for proposing the setting up of a standard rests with the respective industry, including manufacturer and user. The establishment of standards and the adherence to them is, in general, voluntary. This does not exclude that in special cases, especially where safety considerations are concerned, the standards are applied by regulations which may be compulsory. This is in contrast to the situation in many other countries where, particularly as regards electrical equipment, the specifications are enforced through legislation.

Constitution of Main Committees of the British Standards Institution



Another essential question is the correct timing for initiating and for revising a standard. As long as there is a rapid technical development in a particular branch of production it is not advisable to standardize the product lest technical progress be hampered, or else too frequent revisions would become necessary.

The procedure in producing a new standard is, briefly stated, the following. After a request for the standard has been received it is referred by the Director's Committee either to the appropriate Industry Standards Committee or, where one does not exist, to a special industry conference of the interests concerned, or it may be shelved for some reason after consultation with the proposer. The Industry Standards Committee decides whether a request shall be approved, and, if necessary, also reaches a decision if the various opinions expressed in the industry conference have not been reconciled. In case of approval it then draws up the terms of reference for the new Technical Committee. The list of the organizations to be invited to nominate representatives is drawn up in consultation with the B.S.I. staff. The fact that a standard is to be prepared is published in the B.S.I. monthly information sheet, so that interested parties may offer their collaboration. When the scope of the standard has been settled usually a small drafting panel is appointed. The draft, after approval by the Technical Committee, is circulated by the B.S.I. staff to all those who in the opinion of the Technical Committee, especially its secretary and the respective assistant technical director, should be informed. A period of six weeks is given for comment. A final draft is then made, including changes which might be necessary on account of the comments, and the specification is published after the final draft has been approved by the Technical Committee, the B.S.I.'s editorial staff, the Industry Standards Committee and signed by the chairmen of the Divisional Council and of the General Council.

It might be mentioned here that the publicity given to draft and final specifications is much wider in some countries, e.g., in Germany, where these are published *in extenso* in the periodical "Der Maschinenbau" and, as far as the electrical industry is concerned, in the "Elektrotechnische Zeitschrift" (ETZ). While this has certainly some advantages in reaching a wider circle there may be some danger in that a manufacturer might be induced to accept the instructions given in a draft specification too early and be compelled to alter his design afterwards according to the final specification. But there is no doubt that the greater "standard-mindedness" of the German public is due to this wide circulation given to the draft and final standards. The expression "DIN", designating the products standardized by the German Standards Committee, is a household word in Germany, especially since the general introduction of the standardized paper sizes.

The B.S.I. is financed by subscriptions of its members, the sale of specifications and a Government grant. The nearly 700 members are composed of private individuals, local authorities, professional bodies, trade associations, commercial and industrial firms and the nationalized industries. The members are entitled to receive free of charge a certain number of specifications, the Yearbook, the monthly information sheet and the Standards Review.

A library containing the publications of the British and foreign national standardization bodies, but not those of specialized bodies producing their own standards, except those which are compulsorily enforced, is open to the public on weekdays from 10 a.m. to 5 p.m. on the B.S.I.'s premises in Victoria Street, Westminster. British and foreign standard specifications may be bought there at a sales counter. A special Sales Department for British Standards is housed in Gillingham Street, near Victoria Station, and this is the distribution centre for sending out the copies to members and to the public.

A special department of the B.S.I. deals with Certification Marking. The marks certify the compliance with B.S.I. specifications. They may be applied by manufacturers satisfying this requirement and paying an annual licence fee. Of special interest to electronic engineering is the "Radio Interference Free" mark, although it has not yet come into use. The "Plastics" mark is used to a greater extent. The certification marking scheme is as yet only in its beginning, but it is hoped that it will develop.

A part of the British Standard Institution Library

The advantages derived from suitable standardization may be briefly stated (see "Die Technik" 5, 379, 1950):

In production: economical production, reduction of number of sorts;

In commerce: simplification of store keeping, reduction of working capital;

In purchasing: elimination of misunderstandings, shortening of delivery times;

In use: easy procuration of spare parts, guarantee for quality and suitability;

In the drawing office: saving of time and design costs.

A more detailed survey of the advantages and disadvantages may be found in Appendix III of the Lemon Report. Special stress must be laid on the fact that standardization plays a very important part in the defence programme and in the export drive, both as regards raw materials and manufactured goods. In this respect the fourth phase of standardization, that on an international base, must be specially mentioned, an example of which is the recently established unification of screw threads between Great Britain, U.S.A. and Canada. It is hoped that other countries will soon follow suit. The B.S.I. represents the United Kingdom on quite a number of international standardization bodies.

Finally a few words should be said about the special requirements of electronic engineering as regards standardization work. The phrase "electronic engineering" covers a very wide range from normal radio work to heavy engineering. The following standards have already been issued in this field by the B.S.I.:

B.S. 1698 Mercury arc rectifiers,
B.S. 415 Radio receivers (safety rules),
B.S. 448 Electronic-valve bases, caps and holders,
B.S. 1106 Code of practice relating to the use of electronic valves other than cathode-ray tubes.
B.S. 1147 The use of cathode-ray tubes in equipment,
B.S. 1409 Letter symbols for electronic valves.

In addition there is a series of specifications dealing with radio-interference suppression (271, 613, 727, 800, 827, 833, 905, 1597, CP 1001, CP 1002) and a special series of standards for radio components has been drawn up by the Services; some of these are published by the B.S.I. in the BS/RC series. It is expected that these will eventually be withdrawn and replaced by Defence Standards (for Service use) and by a new series of British Standards (for industrial use) based on work of the Radio Industry Council. The specifications 271 and 613 contain *inter alia* the colour codes used for capacitors and resistors.

Other standards are in course of preparation for the rating of high frequency industrial electrical equipment and for performance of radio receivers. To some extent standardization of tests for radio equipment is going on internationally with a view to laying down limits and tolerances for performance as regards rating, temperatures, resistance to humidity, corrosion, vibration, etc.

Perhaps it may be said that electronic engineering is, at least in some of its branches, still in that state of rapid development mentioned above in which standardization cannot be safely undertaken yet. But there is no doubt that the interest in standardization is growing also in this field and this is shown by the following table giving the number of articles dealing with standardization and reviewed in "Science Abstracts" during the last few years:

Year	*Total number of articles*	*Number of electronic articles*
1942	2	—
1943	7	1
1944	7	1
1945	16	2
1946	26	6
1947	13	1
1948	13	2
1949	29	8
1950	25	14

In conclusion the British Standards Institution must be congratulated on occasion of its Golden Jubilee, especially with regard to the "good marks" it received in the two Government Reports. The attention of interested readers is drawn particularly to the book "Fifty Years of British Standards" which will be published this month by the B.S.I. and to the special exhibition to be opened for 12 days at the Science Museum, South Kensington, starting on the 18th of this month, where in collaboration with the Electrical Industry, the Radio Industry Council, the G.P.O., the B.B.C. and other organizations, interesting pieces of equipment, e.g., for the suppression of radio-interference, field strength measurement and the like will be shown.

Acknowledgments

The author wishes to convey his thanks to the Director and members of the staff of the B.S.I. for the kind help he received from them, and to H.M. Stationary Office and the Anglo-American Council on Productivity for permitting quotations from their publications. Thanks are also due to Mr. R. C. Winton for his assistance.

Some Aspects of Electrical Computing (Part 1)

By J. Bell, M.Sc., M.I.E.E. *

AIDS to computing are as old as civilization itself and, as in all other fields of activity, the technique develops as new problems arise to be solved.

Digital computing usually to a scale of ten, but also to other scales, is widely used with mechanical and electrical devices employed to diminish labour and accelerate the processes of computing. It is not, however, proposed to deal with this type of computing, but rather with a method which is more closely allied to the physical form of the problem and has been called analogue computing.

A draughtsman, from known data, for example the length of a line and two angles, can construct a triangle and find graphically the length of the other sides of the figure. This process, however, takes time, and if the data is continuously changing, the answer is never up to date.

Problems in which the solution of triangles is one of the basic requirements arise in gunnery control and prediction instruments in all three fighting Services, but an essential feature of any successful solution is that the answer must be developed continuously as the input information is kept up to date. Time lags of the order of a few seconds in certain cases may make the answer valueless.

The first practical solution of this type of problem was mechanical, the problem being set out to scale with mechanical radius arms and slides for the case of a triangle and other devices also being employed as, for example, a differential for addition, a lever for multiplication and a cam for the introduction of a non-linear function, etc.

During the 1914-1918 War, the art of mechanical computing for fire control purposes was pushed ahead from very small beginnings and has been developed with considerable ingenuity and increasing complexity since that time.

The equipment produced for long range naval gunnery, torpedo calculators and coastal defence gave good service and was not found under practical conditions to be seriously lacking in efficiency. Noteworthy deficiencies, however, existed in the anti-aircraft field, and this was progressively more apparent as aircraft speeds climbed rapidly just before and early in the late war, and so rendered all the predictors obsolete.

The mechanical solution involves usually a very high class of mechanical work and craftsmanship, in order to obtain sufficient accuracy in the result. A considerable time is required for design of equipments to new specifications and for subsequent manufacture in the quantities required. Skilled labour was not available for this purpose and electrical computors were evolved and produced to meet the need.

An outstanding difference between electrical and mechanical computors is that the mechanical version must be designed as a whole, including almost all the individual computing units, wheras in the electrical case it is practicable to build individual computing units on a quantity basis using less skilled labour and combine them to solve the particular problem with a considerable freedom and flexibility of arrangement which is not found possible in the mechanical case.

Statement of the Problem

For those not familiar with the type of problem to be solved, the functions required of an anti-aircraft predictor may be described as follows.

Input information is received from the range finder and telescope sight or radar equipment, usually in the form of a range, an angle of elevation, and an angle in bearing. These data are continually changing and from them must be derived the rate of travel of the target aircraft and its new position in space after a time (t) corresponding to the time of flight of the projectile. There are several possible ways of solving the problem, but one only will be described which is sufficiently typical for our purpose. Taking first the range and the angle of elevation, these can be resolved into a height and a ground range by the solution of the triangle. Then again, the ground range, together with the angle in bearing, can be resolved into geographical distances North or South and East or West from the point of observation. The cartesian quantities thus derived are continuously changing as the target changes position and the rates of change of position must be determined. Assuming that the time (t) is known (the time of flight of the projectile), the rates developed are then multiplied by (t) and the travel corrections from the present to a future position of a target are determined. These corrections must be added to the present position and the solution of the triangles originally carried out is reversed to translate the information back into angles of elevation, bearing, and future range. To the angle of elevation must be added a quantity depending upon the trajectory of the particular type of projectile being used, and this information is then passed to the guns. It will be seen, therefore, that in the case cited, the processes involved are:—

(1) Resolutions from polars to cartesians and vice versa.

(2) Differentiation of a changing quantity.

(3) Multiplication.

(4) Addition.

(5) Computation of variable functions relating to the ballistics.

Electrical computing units were not available for all these processes when the work was first undertaken, but the technique was gradually developed and satisfactory instruments were evolved. It was later found that similar developments were taking place in the U.S.A. at the same time. It is also interesting to note that examination after the war of the progress made in enemy countries during the same period showed that they had been working on somewhat similar lines, but that we were definitely leading in this particular field.

Accuracy of Computation

The degree of accuracy in each computing unit, and in the computor as a whole, which is to be attained must be comparable with the precision of the weapons to be directed or must bear some relation to the geometry of

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the range and target size. Take, for example, an aircraft, the maximum dimension of whose vital part is 6 ft. as seen from the point of observation, at a range of 2,000 yards; the ratio of size/range is 1/1,000. Assuming an ideally accurate weapon, the predictor should have an accuracy of the order of 1/1,000. At longer ranges the inaccuracy of the gun becomes a controlling factor rather than the minimum subtended angle of the target, and other considerations also are present, such as the type of fuse employed and the effective size of the burst of the shell. In general, however, the accuracy figure of 1/1,000th of maximum range of scale of the computor is a good guide to requirements and the computing units were developed to give this order of accuracy under normal operating conditions.

The units which were developed are now de-restricted and may be applied in industry; the main purpose of this paper, therefore, is to make known more widely the characteristics of the instruments, so that technicians who are concerned with the computing, recording, or controlling of functions, mechanisms or processes may have additional tools to hand for the solution of their particular problems.

In order to approach the subject logically, the individual processes required, such as addition and multiplication, etc., will first be considered and the mechanical and electrical devices or instruments suitable for each process will be examined. Examples of combinations of these devices will then be dealt with.

In the sections which follow, describing instruments suitable for certain computing processes, it will be realized that in some instances the inputs are electrical, while in others, the inputs are mechanical, the instrument itself converting the mechanical movement into an electrical quantity.

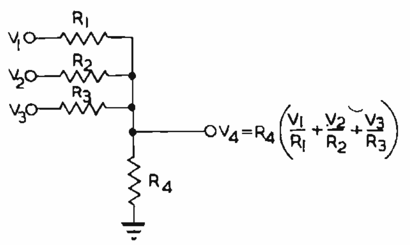

Fig. 1. Adding network

Addition

Mechanically, addition is effected by the use of a differential gear or differential lever, or by a system of cords and pulleys, etc.

Electrically, it is achieved by the addition of A.C. or D.C. potentials if they are isolated from earth and, in the case of A.C., have the same frequency and time phase.

Another method,* however, was successfully developed for voltages having a common source.

Referring to Fig. 1, three voltages, V_1, V_2 and V_3 are indicated as inputs to a network. These voltages would be generated from, say, electronic amplifiers, and currents proportional to the voltages flow in the network, including the common resistor R_4. If R_4 is small by comparison with R_1, R_2 and R_3, then the voltage drop V_4 across R_4 will represent the sum of the currents due to the voltages V_1, V_2 and V_3. The voltage V_4 is, of course, very much smaller than the input voltages and has to be amplified by means of an appropriate, generally electronic, amplifier. For practical purposes the value of V_4 is given by the expression:

$$V_4 = R_4 \ (V_1/R_1 + V_2/R_2 + V_3/R_3)$$

* Used in No. 10 Electrical Predictor developed in the Bell Telephone Laboratory U.S.A.

Multiplication

Mechanically, multiplication may be effected by the use of a lever of variable ratio; an extension of this from linear to circular motion may take the form of a cone or disk with a wheel or ball riding on it and driving a cylinder, one input being the rotation of the cone or disk, and the other input the travel or position of the rider, the output product being the rotation of the cylinder (see Fig. 2).

Electrically, the accepted method has been the use of two potentiometers, see Fig. 3, in which a fixed supply voltage V_0 is applied to one potentiometer causing a certain current to flow. Across this is tapped by a moving tapping set to represent a quantity x, a second potentiometer whose moving contact is set according to a second quantity y. The output voltage is given by the expression $V = kVo\,xy$. This expression neglects an inaccuracy caused by

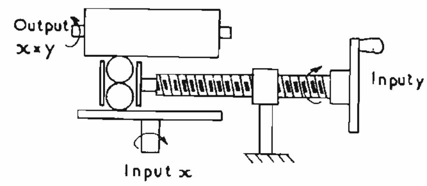

Fig. 2. Mechanical multiplication

the additional and variable drop in voltage along the first potentiometer due to feeding the second. In practice, this may be minimized by using potentiometers of widely different resistance value, the first potentiometer being of low resistance and passing considerable current. An alternative and more correct method of gaining precision with such a network is to interpose an amplifier between the two potentiometers so that the loading on the first potentiometer is reduced to a negligible amount and this alternative is perhaps the only one available if the computation must be carried out with direct current to an accuracy of the order of 0.1 per cent.

An alternative with alternating current is to substitute for the potentiometers one or more auto transformers; the instrument produced for this purpose has been called an "Ipot" (inductive potentiometer). In construction, this is similar to the well-known Variac transformer, but it has

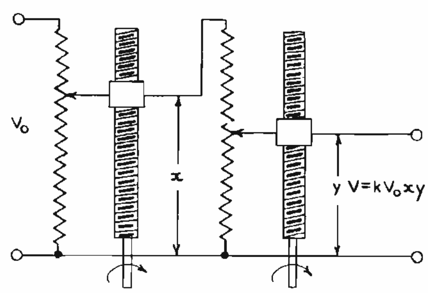

Fig. 3. Electrical multiplication

been built with a much higher degree of precision, so that on performance test the voltage with relation to angle is linear within 1 part in 2,000.

Fig. 4 is a diagram of the Ipot; it will be seen that there are two moving contacts, one which moves over the whole winding (340°) and the second contact which moves over about 60°. As can be seen from the diagram, there are five terminals. The input voltage is usually applied between the second contact terminal 2 and terminal 4. By auto transformer action the whole winding of the Ipot is energized and in effect the small arc between terminals 4 and 5 gives a "below zero" voltage, and the full voltage up to the end of the winding beyond the position of contact 2 may be employed. Multiplication can be carried out by the use of two Ipots connected in a manner similar to the resistance potentiometers shown in Fig. 3.

The low internal impedance of the Ipot, together with the very small magnetizing current enables two or more Ipots to be connected in this way without occasioning excessive voltage drop in the windings of the first Ipot. In addition to the linear winding, the Ipot may be wound with a winding graded within limits to any desired law, see section on Examples of Computing Processes. Further applications of the Ipot will be dealt with in succeeding sections.

Resolution of Polar to Cartesian Co-ordinates, etc.

Resolution from polars to cartesians involves two processes, firstly the setting up of the polar quantity in angle θ and magnitude r, and secondly the resolution of this into two quantities $r \sin \theta$ and $r \cos \theta$. It may be observed that the quantities $r \sin \theta$ and $r \cos \theta$ are products, thus the two processes are really (i) a multiplication, and (ii) a determination of sine and cosine functions.

Mechanically, the operation is effected by the use of a pin which can be set along a radius arm, the pin also engaging with two slides set at right angles to each other, the positions of the slides from a datum position gives the cartesians quantities required.

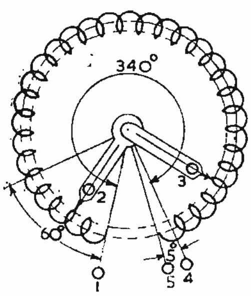

Fig. 4. Ipot

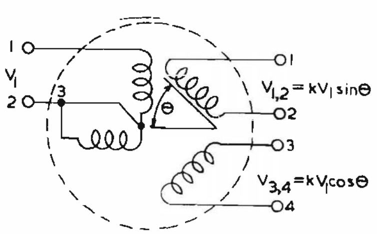

Fig. 5. Resolver No. 1. Resolution of polars to cartesians

Electrically, the operation can be achieved by means of specially graded potentiometers, or alternatively, a potential can be built up across a pile of layers of resistive material or a special flat commutator on either of which a brush or systems of brushes bear, constrained to move in a circular manner.* The natural way to resolve electrically, however, for A.C. working, is to use two or more coaxial coils as in a goniometer, the flux set up by one coil or set of coils providing a magnetic field linked with the other coil or set of coils and inducing appropriate sine and cosine voltages in them. Such an instrument is the Magslip Resolver, two types of which exist—No. 1 being the simple type and No. 2 an instrument designed to operate in conjunction with feed-back amplifiers.

For precise working the No. 1 Resolver must operate on constant voltage, thus it is only possible to derive from it the circular functions, and the multiplication by the value of the polar quantity must be carried out separately by the use of a potentiometer or Ipot.

The No. 2 Resolver, however, was designed to carry out the complete operation, its associated amplifiers providing the conditions of excitation requisite for precise operation on variable voltage.

The Magslip Resolver No. 1 was developed first, and is intended for use on 50V 50c/s supply. Two windings, spaced at 90 degrees with respect to each other, are provided on both rotor and stator. Under normal conditions of operation, the rotor is excited on one winding only, the other winding being short-circuited on itself to provide a means of compensation against unwanted quadrature components of the magnetic field which may, for example, arise from the action of eddy currents in the stator iron or output currents in the stator windings. A magnetic field of constant magnitude is set up by the rotor and this field is oriented in operation of the instrument by rotation of the rotor. The alternating magnetic field links the two stator windings which are at right angles to each other and yield alternating potentials corresponding in magnitude respectively to the sine and cosine of the angle of the exciting winding of the rotor with respect to the stator. The arrangement of the Resolver windings is shown diagrammatically in Fig. 5.

It is possible also to use this Resolver on a controlled variable voltage supply, the voltage being varied in accordance with some desired function. The output voltages from the Resolver are thus:

$$V_{12} = kE \cos \theta$$
$$V_{34} = kE \sin \theta$$

Because of the electrical losses in the Resolver, however, the output voltages do not correspond precisely with the variable input voltage, and it has been found that when

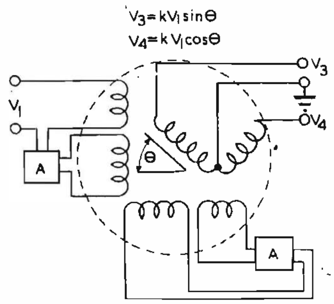

Fig. 6. Resolver No. 2. Resolution of polars to cartesians

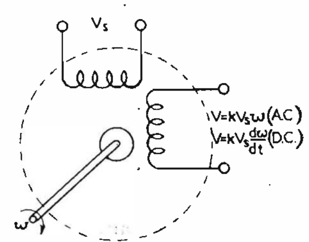

Fig. 7. Induction generator. Voltage proportional to speed with A.C. supply. Voltage proportional to acceleration with D.C. supply

used in this way the overall precision of the No. 1 Resolver is about $\pm$ 1 per cent. To overcome this difficulty and regain the desirable accuracy of $\pm$ 0.1 per cent on variable voltage input the No. 2 Resolver was designed.

The Magslip Resolver No. 2, together with the associated amplifiers, is shown diagrammatically in Fig. 6. The instrument has two-phase windings on both rotor and stator, but in addition to the main stator winding there is an auxiliary two-phase winding also wound on the stator on the same axis as the main winding. The auxiliary winding may be regarded as serving to measure the induced voltage or working flux in the instrument which the current in the main winding produces. In practice, the input voltage is fed to the amplifier in series with the auxiliary winding of any one phase, the input to the amplifier is thus the difference in voltage between the input, or applied voltage, and the voltage induced in the auxiliary winding. The output of the amplifier is fed to the main winding of the same phase. Assuming for the moment that the gain of the amplifier is infinite, then current will flow to excite the Resolver until the voltage of the auxiliary winding balances the applied voltage exactly in magnitude and time phase. If the rotor is set to any angle θ with relation to the stator, the outputs from its windings will be $V \sin \theta$ and $V \cos \theta$ where V is the input voltage applied to the Resolver and amplifier circuit, assuming that the transformation ratio between rotor and stator is unity.

The Resolver may be excited on both phases, in which

* See J. Bell—Data Transmission Systems. *Journal I.E.E.* Vol. 94, part IIA, No. 2, page 225.

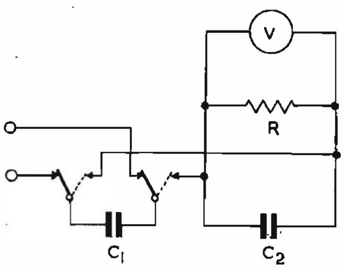

Fig. 8. Electrical rate measurement

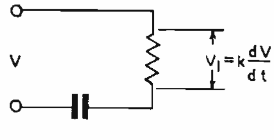

Fig. 9. Electrical differentiation

case the total magnetic flux set up in the instrument is a true vector sum of the fluxes due to Phases I and II, and the outputs from the rotor will again be sine and cosine functions of this total flux.

Examples of the application of these Resolvers appear later.

Rate or Speed Measurement

The speed to be measured is generally, or can readily be converted into, an angular velocity. Mechanically this can be measured by means of a centrifugal device, or alternatively by means of a sequence or timing control of some kind, the angular rotation over a given time may be measured. Another method is to use the properties of a gyroscope and measure angular velocity in terms of a precessional torque.

Electrically the obvious way is to use a generator driven by the unit whose speed is to be measured; the generator may be a D.C. or an A.C. type. Among the latter a very useful form is an induction generator excited by single phase A.C. and yielding an output voltage proportional to the speed at which it is driven and of the same frequency as the supply. This is shown diagrammatically in Fig. 7.

Another method is to use two capacitors as shown in Fig. 8, C_1 being much smaller than C_2 and being connected in turn first to the D.C. supply and then to capacitor C_2 at a frequency depending on the speed to be measured. An appropriate leak R is connected across this capacitor, and the voltage V is a measure of the speed, approaching exponentially to the correct value if the speed is constant.

If the distance from a given datum of the object whose speed is to be measured is represented by a D.C. voltage the measurement can be performed by the use of a resistance-capacitance network. A simple example is shown in Fig. 9; the current flowing into the capacitor is a measure of the rate of change of voltage, and consequently of the speed of the object. An error will be present with changing speed, due to the time constant of the resistance-capacitance network, the value of the time constant must therefore be chosen according to the requirements of the application.

Acceleration Measurement

The measurement of acceleration may also be required for computing or for servo stabilization.

The recognized mechanical method is to use a mass and measure the deflexion of a spring which applies a force to impart the motion to be measured to the mass. Either translational or rotational motion may be examined in this way. The measurement may appear in an electrical form if, for example, a piezo-electric crystal is used instead of the spring in the wholly mechanical method.

A further method of measuring rotational acceleration is available using the induction generator described in the foregoing section. Instead of supplying the generator with A.C., a direct current is used to excite one phase and a direct voltage of appropriate polarity and magnitude is generated by the second phase, giving a measure of the positive or negative acceleration of the rotor of the generator (see Fig. 7).

Computation of Variable Functions

Some problems involve functions which are dependent on two or more factors. An example of this is seen in the relation between the time of flight of a projectile and the range to which it travels. In the case of gun and target at the same level (e.g., sea level) there is a fixed, although non-linear, relation between range and time of flight. (This assumes a known fixed muzzle velocity and constant atmospheric conditions). In the anti-aircraft problem, however, the gun and target are seldom at the same level and another variable is present due to the work done against gravity in raising the projectile. Thus the time of flight may be expressed as a function of two variables, namely range and angle of elevation of the gun.

The mechanical solution for this is to use a series of cams cut for the correct relation each for a given angle of elevation, or more ideally a three-dimensional cam is made embodying effectively in its surface an infinite number of such cams. A three-dimensional cam is shown in Fig. 10. The cam is rotated to the required "range" (A) and translated axially according to the angle of elevation (B), the rider moving vertically to indicate the time of flight.

The electrical equivalent of the three-dimensional cam is made up in a similar way to the mechanical version of an infinite number of simple cams, but instead of a physical embodiment of the large number of simple cams the effect is produced in the electrical case by using one non-linear function given by a resistive potentiometer or an Ipot and altering the conditions of its operation by other potentiometers or attenuators of either type connected in the supply and/or output circuits of the main potentiometer. Fig. 11 shows an electrical variable function network operating from a supply V_0 and producing an output voltage which is a function of two variables A and B. In the diagram the main non-linear function is given by the potentiometer 1—2 whose tapping point is controlled according to the quantity A; it is modified by the series connected tapped impedance 2—3, and also by the series inserted potential due to the potentiometer 4—5, the tapping points or contacts on 2—3

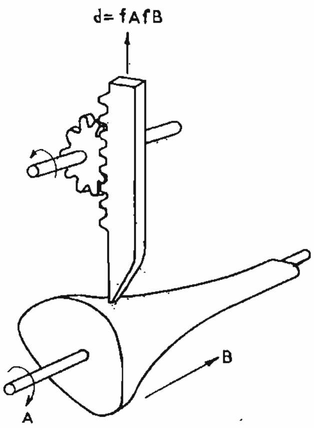

Fig. 10. Three-dimensional cam

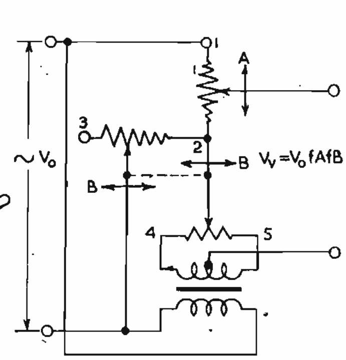

Fig. 11. Electrical equivalent of a three-dimensional cam

and 4—5 being ganged together and operated according to the quantity B.

It will be appreciated that the modifying devices 2—3 and 4—5 are merely typical; many other arrangements may be used to effect the change of the main function into a compound function of two variables.

(To be continued)

Electrometer Valve Balanced Circuits

with special reference to the Ferranti BM4A

By H. A. Hughes, B.Sc., A.R.C.S., A.Inst.P. *

Progress in electrometer valve balanced circuit design is reviewed. Equations are derived which describe the behaviour of both the Barth and Caldwell type of balanced circuits. Relations between certain parameters are given which obtain under stated conditions of optimum performance, and it is shown that the electrometer valve characteristics impose restrictions on the value of supply voltage necessary to balance the circuit. Data are presented relating to the use of the Ferranti electrometer valve, type BM4 A, in balanced circuits.

BALANCING circuits for electrometer valves of the space-charge tetrode type are primarily intended to minimize instability caused by variations in the valve power supply. They also tend to compensate for certain changes in the electrodes of the valve itself. Two types of circuit have been developed, these being (1) the differential output circuit in which the potential between anode and some point on a resistor in series with the space-change grid is independent of the supply voltage, and (2) the single-sided circuit, where the output is taken across the anode load resistor. Amplification of the output from the differential circuit necessitates the use of a twin valve differential output stage, whereas only a single input valve is required to deal with signals from the second type of circuit. This may be considered a simplification to the design of a D.C. amplifier.

The balance conditions for both these types of circuit have been derived previously and experimental data on their performance quoted. The following sections present the analyses in a more extended form, with some data on a particular British electrometer valve. All data so far published concerns American valves not now readily obtainable in this country.

Conditions for Circuit Performance

The following conditions apply to the performance of either type of balanced circuit: (1) small changes in power supply voltage should not affect the output potential, i.e., a balance point should exist; (2) this balance point should occur at or very near to the recommended valve rating. The reasons for operating a valve at this rating are explained in Radio Valve Practice, 1st Edition, page 5 (issued by the B.V.A., 1948). In the case of an electrometer valve, two faults which may arise are high grid current due to a control grid potential above the rated value, and increased noise at too high a heater current; (3) the balance point should occur at the rated heater current over the whole range of operating control grid potential. If the valve is being used as a null indicator for current measurement (i.e., in the Townsend balance method), this condition is not necessary, but if current is measured by a direct deflexion method the condition must be fulfilled; (4) the circuit should be easy to adjust; (5) in some applications it is advantageous if the circuit can be balanced with almost any valve of the same type without changing all the circuit constants; (6) where the circuit is to be used as the input stage of an amplifier, the gain should be as high as possible. This is particularly important in the case of feed-back amplifiers where the overall stability is dependent on the gain of the first stage.

Differential Output Circuits

REVIEW OF PROGRESS IN CIRCUIT DESIGN

Many of the original circuits devised with a view to making the anode current of a valve independent of small changes in supply voltage required two valves (usually triodes) with matched characteristics.[1,2] These were difficult to obtain, and although this type of circuit gives an improvement of stability toward changes which affect both valves equally, most workers favoured the single space-charge tetrode valve in a suitable network. However, it may be mentioned that a split electrometer valve, having a common cathode (such as described by Lafferty and Kingdon[3] in the U.S.A., and Brentano and Inglesby[4] in Great Britain, the latter's work leading eventually to the design of the Ferranti type BM4 A) would reduce the variations due to spontaneous cathode emission changes.

A review of balanced circuits has been made by Penick[5] who described many earlier circuits which were eventually superseded by one due to Dubridge and Brown[6] which has been used successfully by many workers, and is shown in Fig. 1. Some difficulty was experienced in balancing this circuit for valves of different characteristics, and a modification was suggested by Penick and developed independently by Barth[7] in which the leads from anode and space-charge grid were attached to separate taps on the resistance R_3 (see Fig. 2) thus introducing an additional element of flexibility into the circuit.

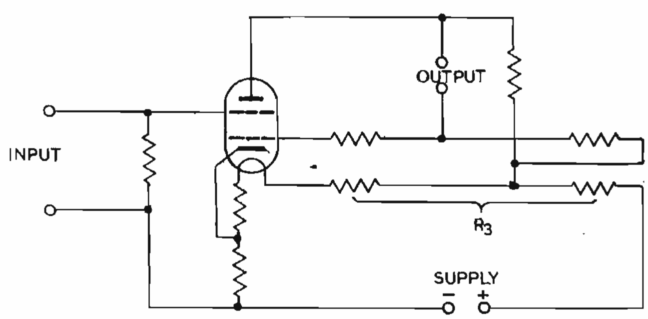

Fig. 1. Dubridge and Brown circuit, with input resistor for current measurement by direct deflexion method

EXISTING EXPERIMENTAL DATA ON BARTH CIRCUIT

The properties of the Barth circuit have been investigated experimentally by Penick[5] and Spencer and Schultz.[8] They found that with most valves of the types tested (General Electric FP54 and Western Electric D-96475), conditions (1), (2) and (4) could be fulfilled. Although the value of the filament current at the balance point usually shifted with control grid potential, it could be made to coincide with the rated filament current over a fairly wide range (condition (3)) after some seemingly arbitrary adjustments of the circuit constants. It has already been mentioned that the circuit was designed to enable the incorporation of valves of different characteristics as required in condition (5). An observation by Penick that the slope of the output-filament current curve at the rated value

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decreased with increasing value of supply voltage has little value because the gain of the circuit in each case was not quoted. It will be obvious that all observations should be compared after allowing for circuit gain. Valves with low emission sometimes could not be balanced, and other valves gave two balance points which could be moved together by suitable adjustments of the circuit.

Theoretical Analysis of Barth Circuit

Penick has derived an equation which describes the Barth circuit under the conditions of balance. No attempt has been made to extend this analysis to formulate relations between circuit parameters under the above stated conditions of optimum performance. These relations would decide the possibility of the valve being balanced, the value of supply voltage necessary, and would obviate purely arbitrary adjustment of the circuit. It may be mentioned that Caldwell[9] has carried out an analysis of a single-sided circuit to be described later in this paper, to a point where the minimum value of supply voltage required to balance the circuit can be evaluated. His treatment has been followed here, and extended to bring out other properties of the circuit.

The valve shown in Fig. 2 is an indirectly heated type, and the resistance R_c has been included between the cathode and negative end of the heater as is recommended by the manufacturers of the BM4A. This resistance introduces a further parameter, which, as will be shown, can greatly modify the balance conditions. The voltages e_a, e_s and e_g are measured from the cathode; e_h is the voltage drop across the heater, and e_o is the output voltage measured between anode and the junction of R_4 and R_n. i_a and i_s are assumed to be much smaller than i_h. A set of

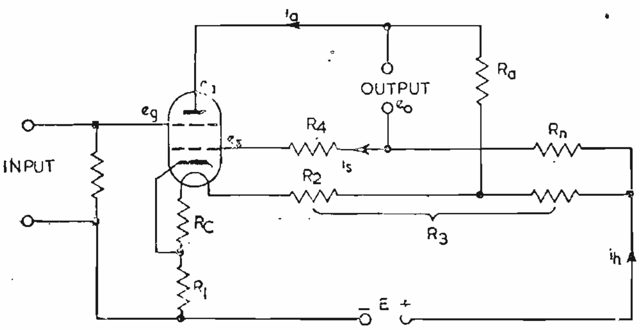

Fig. 2. Barth circuit with input resistor for current measurement by direct deflexion method

equations which describe the circuit for no input signal is:

$$e_g = -i_h \,.\, R_1 \quad \ldots\ldots (1)$$

$$e_s = e_h + i_h\,(R_c + R_3) - i_s\,(R_4 + R_n) \quad \ldots\ldots (2)$$

$$e_a = e_h + i_h\,(R_c + R_2) - i_a \,.\, R_a \quad \ldots\ldots (3)$$

$$E = e_h + i_h\,(R_c + R_1 + R_3) \quad \ldots\ldots (4)$$

$$e_o = e_a - e_s - i_s \,.\, R_4 \quad \ldots\ldots (5)$$

The anode current can be expanded in a Taylor's series about the operating point,* and if only terms in first derivatives are retained,

$$\Delta i_a = A_g \,.\, \Delta e_g + A_h \,.\, \Delta i_h + A_s \,.\, \Delta e_s + A_a \,.\, \Delta e_a \quad \ldots (6)$$

where

$$A_g = \partial i_a/\partial e_g;\; A_h = \partial i_a/\partial i_h;\; A_s = \partial i_a/\partial e_s;\; A_a = \partial i_a/\partial e_a$$

Similarly,

$$\Delta i_s = S_g \,.\, \Delta e_g + S_h \,.\, \Delta i_h + S_s \,.\, \Delta e_s + S_a \,.\, \Delta e_a \quad \ldots (7)$$

where

$$S_g = \partial i_s/\partial e_g;\; S_h = \partial i_s/\partial i_h;\; S_s = \partial i_s/\partial e_s;\; S_a = \partial i_s/\partial e_a$$

The change in e_a produced by a change in i_h can now be found. From Equations (1), (2) and (3) respectively,

$$\Delta e_g = -\Delta i_h \,.\, R_1 \quad \ldots\ldots (8)$$

$$\Delta e_s = \Delta i_h(r_h + R_c + R_3) - \Delta i_s(R_4 + R_n) \quad \ldots\ldots (9)$$

$$\Delta e_a = \Delta i_h(r_h + R_c + R_2) - \Delta i_a \,.\, R_a \quad \ldots\ldots (10)$$

where $r_h = \partial e_h/\partial i_h$

Eliminating Δi_s and Δe_g, Equation (7) becomes

$$\Delta e_s = \Delta i_h \frac{r_h + R_c + R_3 + (R_4 + R_n)(S_g \,.\, R_1 - S_h)}{S_s(R_4 + R_n) + 1} - \Delta e_a \frac{S_a(R_4 + R_n)}{S_s(R_4 + R_n) + 1} \quad \ldots\ldots (11)$$

Similarly, by eliminating Δi_a and Δe_g, Equation (7) becomes

$$\Delta e_a = \Delta i_h \frac{r_h + R_c + R_2 + R_a(A_g \,.\, R_1 - A_h)}{A_a \,.\, R_a + 1} - \Delta e_s \,.\, \frac{A_s \,.\, R_a}{A_a \,.\, R_a + 1} \quad \ldots\ldots (12)$$

Eliminating Δe_s between Equations (11) and (12)

$$\Delta e_a = \Delta i_h \,.\, \frac{[r_h + R_c + R_2 + R_a(A_g \,.\, R_1 - A_h)][S_s(R_4 + R_n) + 1] - R_a \,.\, A_s\,[r_h + R_c + R_2 + (R_4 + R_n)(S_g \,.\, R_1 - S_h)]}{(A_a \,.\, R_a + 1)[S_s(R_4 + R_n) + 1] - R_a \,.\, A_s \,.\, S_a\,(R_4 + R_n)}$$

$$= K_1 \,.\, \Delta i_h \quad \ldots\ldots (13)$$

Eliminating Δe_a from Equations (12) and (13)

$$\Delta e_s = \Delta i_h \,.\, \frac{r_h + R_c + R_3 + (R_4 + R_n)(S_g \,.\, R_1 - S_h)}{S_s(R_4 + R_n) + 1}$$

$$- \Delta i_h \,.\, \frac{S_a(R_4 + R_n)\left\{[r_h + R_c + R_2 + R_a(A_g \,.\, R_1 - A_h)][S_s(R_4 + R_n) + 1] - R_a.A_s[r_h + R_c + R_2 + (R_4 + R_n)(S_g.R_1 - S_h)]\right\}}{[S_s(R_4 + R_n) + 1]\left\{(A_a \,.\, R_a + 1)[S_s(R_4 + R_n) + 1] - R_a \,.\, A_s \,.\, S_a\,(R_4 + R_n)\right\}}$$

$$= K_2 \,.\, \Delta i_h \quad \ldots\ldots (14)$$

From Equation (9)

$$\Delta i_s = \Delta i_h \,.\, \frac{r_h + R_c + R_3}{R_4 + R_n} - \Delta e_s \,.\, \frac{1}{R_4 + R_n}$$

Substituting the value of Δe_s obtained from Equation (14)

$$\Delta i_s = \frac{r_h + R_c + R_3 - K_2}{R_4 + R_n} = K_3 \,.\, \Delta i_h \quad \ldots\ldots (15)$$

The condition that the output voltage be independent of the supply voltage at the operating point, is from Equation (5),

$$\Delta e_o = \Delta e_a - \Delta e_s - \Delta i_s \,.\, R_4 = O$$

$$\text{i.e., } K_1 - K_2 - R_4 K_3 = O \quad \ldots\ldots (16)$$

Equation (16) involves circuit resistances and valve characteristics only. Numerical values for R_1 and R_4 can be fixed from Equation (1) and the added condition that $e_o = O$ respectively. R_n and R_a can be expressed in terms of R_3 and R_2 from Equations (2) and (3) respectively. If these values are substituted into Equation (16) a relation between R_2 and R_3 results, which may be expressed in the form

$$R_2 = \frac{aR_3^3 + bR_3^2 + cR_3 + d}{eR_3^3 + fR_3^2 + gR_3 + h} \quad \ldots\ldots (17)$$

in which the coefficients a, b, etc., are functions of valve characteristics only. To give positive values of R_2, R_3 must be greater than the positive root of the equation

$$aR_3^3 + bR_3^2 + cR_3 + d = O \quad \ldots\ldots (18)^*$$

It should also be noted that a minimum value of R_3 is given by applying the condition that $(R_1 + R_h)$ must be positive. This leads to the relation $R_3 > (e_s - e_h)/i_h - R_c$ (from Equation (2)). The value chosen for R_0 thus deter-

* This method of presentation of valve characteristics was first proposed by Carson, J. R.: *Proc. I.R.E.*, 7, 187, 1919.

* This is not strictly true unless $dR_2/dR_3 > O$ for values of R_3 greater than that given by equation (18) i.e., unless $3aR_3^2 + 2bR_3 + C > R_2(3eR_3^2 + 2fR_3 + g)$.

mines which relation gives the minimum value of R_3, and hence the minimum value for the supply voltage E necessary for balance.

It now remains to examine what restrictions are placed upon the values of R_2 and R_3 in order that condition (3) (no variation of balance point with control grid potential) is satisfied. If the control grid potential is changed to some new value (by keeping R_1 fixed and injecting a signal into the control grid) the values of e_s, i_s, e_a, i_a, e_o and all the characteristics A_g, S_g, etc., will change to some new unknown values. A new series of equations similar to Equations (1)-(16) will now hold. The relation between R_2 and R_3 will now be

$$R_2 = \frac{a_1 R_3^3 + b_1 R_3^2 + c_1 R_3 + d_1}{e_1 R_3^3 + f_1 R_3^2 + g_1 R_3 + h_1} \ldots\ldots \quad (19)$$

The condition that Equations (17) and (19) are satisfied by the same values of R_2 is

$$\frac{aR_3^3 + bR_3^2 + cR_3 + d}{eR_3^3 + fR_3^2 + gR_3 + h} = \frac{a_1 R_3^3 + b_1 R_3^2 + c_1 R_3 + d_1}{e_1 R_3^3 + f_1 R_3^3 + g_1 R_3 + h_1} \ldots\ldots\ldots\ldots \quad (20)$$

The positive roots of this equation which give positive values of R_2 are valid practically. The new values of e_s and e_a can be fixed at any desired value consistent with satisfactory operation of the valve at the new control grid potential. Hence the corresponding values of i_s and i_a, A_g, S_g, etc., can be measured, and thus the coefficients a_1, b_1, etc., may be evaluated. If the values of R_2 and R_3 allow the circuit to be balanced at the rated heater current at two different control grid potentials, and if this range of potentials is fairly small, the circuit should be balanced at the same heater current for intermediate values of control grid voltage. Should the required value of R_3 be so large as to necessitate an inconvenient value of supply voltage, the calculation could be repeated using some other values of e_s and e_a.

The ease of adjustment of the circuit is dependent upon the slope of the output-heater current curve near the balance point. It is not possible to state a mathematical relationship between e_o and i_h, as a knowledge of the variation of valve characteristics with heater current and electrode voltages is involved.* Thus a theoretical evaluation of the circuit constants necessary to fulfil condition (4) cannot be made exactly. However, an inspection of Equations (2) and (3) indicates that the change in electrode potentials e_s and e_a produced as a result of varying R_3 and R_2 respectively will diminish with increasing values of R_c. Although this does not affect the breadth of balance of the circuit, it does imply that experimental investigation of the circuit will be simplified.

It may be noted that unless the valve is to be operated at a fixed control grid potential as a null indicator, only values of R_2 and R_3 which satisfy Equations (19) and (20) are permissible, and then the shape of the e_o-i_h curve will depend only on the valve characteristics.

The breadth of balance of the circuit will appear to be greater as the gain of the circuit decreases. For this reason all experimental observations should be plotted after allowing for differences in gain. The voltage gain of the circuit can be derived from Equations (6)-(10) and the relation $\Delta e_o = \Delta e_a - \Delta e_s - \Delta i_s R_4$. The resulting expression is:

$$m = \Delta e_o / \Delta e_g = \frac{S_g \,.\, R_a A_s(R_4 + R_n) - R_a A_g[1 + S_s(R_4 + R_n)] + R_n S_g(1 + R_a A_a) - R_n \,.\, S_a \,.\, R_a \,.\, A_g}{(1 + R_a \,.\, A_a)[1 + S_s(R_4 + R_n)] - R_a \,.\, A_s \,.\, S_a(R_4 + R_n)}$$

In order to find the value of R_3 which would make the gain a maximum value, it is necessary to express all circuit resistances in terms of R_3 and equate dm/dR_3 to zero. In general this value of R_3 would differ from that required to fulfil the other conditions, and a compromise would have to be made experimentally.

* The linear relation between eo and i_h resulting from inegration of the equation $\Delta e_o = \Delta h\ (K_1 - K_2 - R_4 K_3)$ is not valid owing to the non-inclusion of derivatives higher than the first in Equations (6) and (7).

Limitations of theoretical predictions of circuit performance

It has thus been shown that from measurements of characteristics of a given valve, it is possible to decide whether it can be balanced in the Barth type of bridge circuit under any given operating conditions, the minimum value of supply voltage necessary, and the value for the gain of the circuit under the conditions of balance. The breadth of balance and amount of shift from a given heater current rating at different electrode potentials can only be determined experimentally. It is highly probable, for instance, that the shift of balance "point" with control grid potential is only very slight where the breadth of balance is large. This could not be indicated theoretically.

It is obvious that the conditions of balance will change if for any reason the valve characteristics alter. Emission changes such as might occur in a poorly activated (or over activated) valve would be the most likely cause of this. Thus it is advisable to run the valve under normal operating conditions for some time, keeping a check on characteristics, before undertaking any experimental or theoretical investigations such as have been described.

Single-sided output circuit

To the author's knowledge only one circuit has been described in the literature in which the anode voltage, as measured from the negative side of the grid bias resistor, is independent of the supply voltage at the valve operating point. This circuit is due to Caldwell and was designed

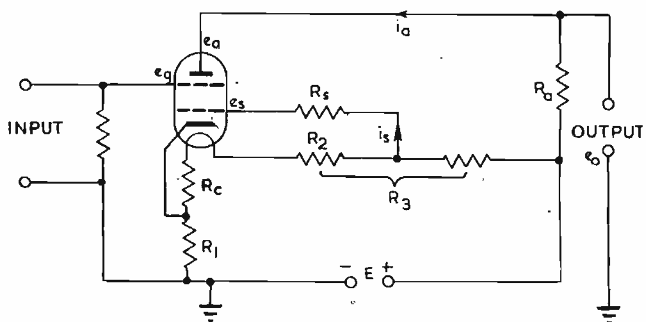

Fig. 3. Caldwell circuit with input resistor for current measurement by direct deflexion method

in order that a subsequent D.C. amplifier should have a single input valve. It is shown in Fig. 3. The analysis of the circuit has been made by Caldwell and only the final result will be quoted. The condition that the output voltage be independent of supply voltage is:

$$(1 + R_s \,.\, S_s)[r_h + R_c + R_3 + R_a(A_g \,.\, R_1 - A_h)]$$
$$- R_a \,.\, A_s[r_h + R_c + R_2 + R_s(S_g \,.\, R_1 - S_h)]$$
$$+ R_1[(1 + A_a R_a)(1 + R_s S_s) - R_a . A_s . S_a . R_s] = O \ \ldots . \quad (21)$$

Expressing R_s and R_a in terms of R_2 and R_3, this may be written in the form

$$R_2 = (jR_3 + k)/(lR_3 + m) \ \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

where the coefficients j, k, etc., are again functions of valve characteristics only. For R_2 to be positive, R_3 must be greater than $-k/j$. A minimum value of R_3 is also obtained from the condition that R_a must be positive; i.e., $R_3 > (e_a - e_h)/i_h - R_c$. The value of R_c may thus determine which relation gives the minimum value for R_3, and hence the supply voltage necessary for balance.

The condition that the circuit be balanced at two values

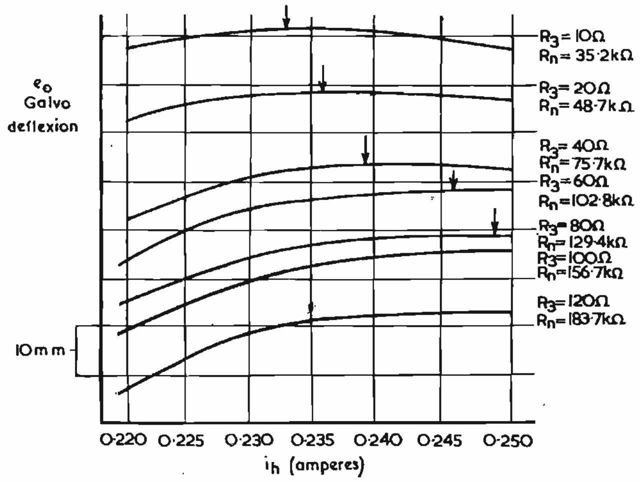

Fig. 4. Barth circuit—determination of minimum value of R_3 necessary for balance (the vertical separation of the curves is arbitrary)
$R_c = 24.5\Omega$, $R_1 = 12.7\Omega$, $R_2 = O$, $R_4 = 11.4k\Omega$, $R_a = 20.6k\Omega$

of control grid potential is:

$$(jR_3 + k)/(lR_3 + m) = (j_1R_3 + k_1)/(l_1R_3 + m_1) \quad .. (23)$$

where j_1, etc., are the values of coefficients obtaining under the new operating conditions. The points stated about the Barth circuit under these conditions also apply here.

The voltage gain of the circuit may be shown to be:

$$m = \frac{R_a[A_g(1 + S_sR_s) - A_s \, . \, R_s \, . \, S_s]}{(1 + A_aR_a)(1 + S_sR_s) - A_s \, . \, R_s \, . \, S_a \, . \, R_a}$$

A value of R_3 can be found which will make the gain a maximum value, but as before it will generally differ from that required to fulfil the other conditions.

The remarks made in the previous section regarding the limitations of theoretical predictions of circuit performance apply equally well to the Caldwell circuit.

Experimental investigation with a Ferranti type BM4A

The Ferranti type BM4A is an indirectly heated space-charge tetrode with recommended anode and screen voltages of 6V and 4V respectively. The manufacturers also recommend that the cathode be maintained at 6 to 10V negative relative to the negative end of the heater. This has the effect of reducing the value of grid current and increasing grid current stability. Measurements of output voltages were made with a Cambridge spot galvanometer (sensitivity approximately 30mm/μA) in series with a 1MΩ resistor, so that 1mV change of output was indicated by only 0.03mm deflexion. However, this sensitivity is sufficient for the preliminary investigations on a balanced circuit. Final adjustments on a circuit used for current measurement would be made using a much more sensitive arrangement.

Barth Circuit.

At a grid potential of -3V, and with $R_c = 24.5\Omega$ the characteristics are such that the minimum value of R_3 required for balance derived from Equation (18) is 25Ω. In order to check on this prediction the circuit was set up with $R_2 = O$, and $e_o - i_h$ curves plotted for a range of values of R_3. The minimum value of R_3 required for balance can be interpolated from this family of curves as being about 20Ω. The difference between this and the theoretical value probably lies in errors in adjusting the various electrode voltages. These curves are shown in Fig. 4. For values of R_3 greater than 20Ω the balance point occurs at heater currents higher than the rated value, but can be moved back towards the rated value by increasing R_2 to the value required by Equation (17). Increasing R_2 when R_3 is less than 20Ω merely moves the balance point away from the rated value as would be expected. It can be seen from the curves that comparatively large changes in R_3 are required to move the balance point through a small range of heater current. This can be attributed to the fairly large value of R_c used,

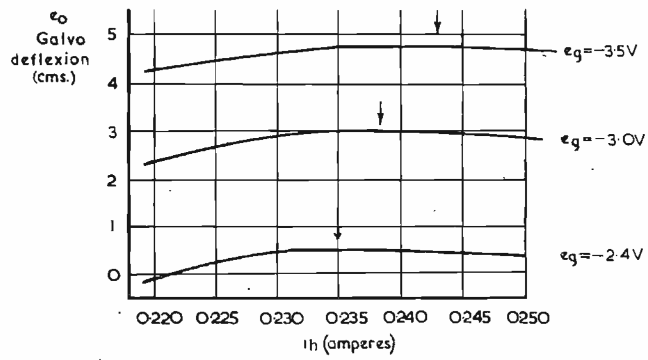

Fig. 5. Barth circuit—variation of balance point with control grid potential
$R_c = 24.5\Omega$, $R_1 = 12.7\Omega$, $R_2 = O$, $R_3 = 20\Omega$, $R_4 = 14.3k\Omega$, $R_n = 48.7k\Omega$
$R_a = 21.9k\Omega$

as has been mentioned in remarks on ease of adjustment of the circuit.

Fig. 5 shows the $e_o - i_h$ curves with $R_3 = 20\Omega$ (the minimum value for balance) at three different values of control grid potential. It can be seen that the balance shifts considerably. It should be mentioned that in the actual design of a circuit for current measurement by a direct deflexion method, the constants would be adjusted so that a full scale reading would be obtained with a change of about 0.1V only in grid potential. The large values of grid potential change used in this experiment were chosen to illustrate the point more clearly. The value of R_3 derived from Equation (20) in order that the circuit be balanced at both grid potentials -2.5 V and -3.0V is about 500Ω. This involved the use of a supply voltage which was not available. However, R_3 was chosen at the highest convenient value (about 200Ω), R_2 calculated from Equation (20), and the curves plotted for the same grid potentials. The shift in this case was considerably reduced, and it is reasonable to assume that it would continue to decrease until the predicted value of R_3 was reached, where no shift should exist.

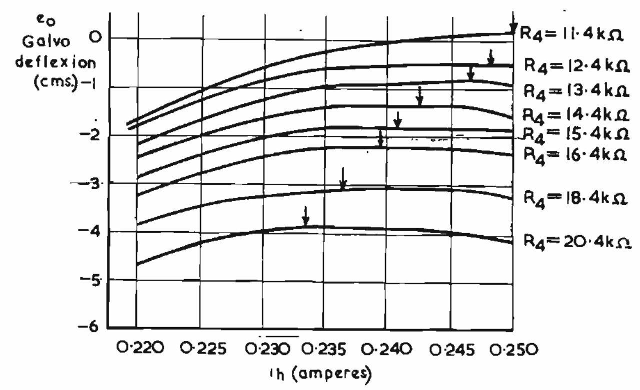

Fig. 6. Barth circuit—variation of balance point with R_4
$R_c = 24.5\Omega$, $R_1 = 12.7\Omega$, $R_2 = O$, $R_3 = 90\Omega$, $R_n = 11.4k\Omega$, $R_a = 21.5k\Omega$

It has been noticed by other investigators[8] that R_4 may be used as a means of shifting the balance point of this circuit. From an inspection of the expression for the circuit gain it can be seen that little difference to its value will be made by varying R_4, providing that R_n is large. Equation (2) also shows that e_s will be relatively unaffected by changes in R_4 providing R_n is large. Thus it seems that R_4 is a suitable parameter to use as a circuit adjustment. Experimental evidence supports this view, and

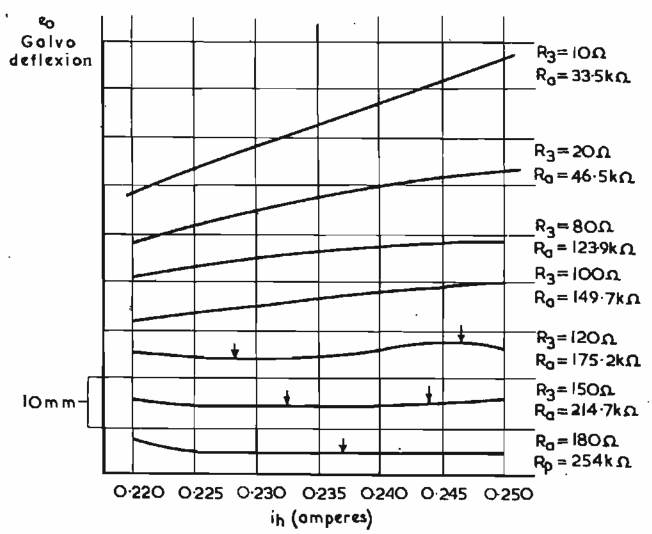

Fig. 7. Caldwell circuit—determination of minimum value of R_3 necessary for balance (the vertical separation of the curves is arbitrary)
R_c = 24.5Ω, R_1 = 12.7Ω, R_2 = O, R_3 = 33.3kΩ

Fig. 6 shows a family of curves for different values of R_4 with $R_2 = O$ and $R_3 = 90\Omega$.

A calculation made for the case $R_c = O$ failed to produce a positive value of R_3 from solution of Equation (18). This result was confirmed experimentally. However, it may be mentioned that changing R_4 could possibly produce a balance in such a case. It was thought that, subject to the grid current being satisfactory, a balance with $R_c = O$ might reduce the value of supply voltage necessary. This does not seem to be so.

CALDWELL CIRCUIT.

A similar experimental procedure was carried out with the valve in the Caldwell circuit. In this case the standing output voltage was balanced out by a potentiometer. The minimum value of R_3 required for balance at the rated heater current is seen from Fig. 7 to be 180Ω, in close agreement with the predicted value. No balance point occurs over any part of the range of heater current investigated for values of R_3 less than 120Ω. At this value the $e_o - i_h$ curve has two balance points, which move together as R_3 is increased up to 180Ω, when a broad plateau is present. This plateau has been observed by Caldwell himself with this circuit, and by Spencer and Schultz with the Barth circuit. It is a characteristic of the valve, rather than the circuit, and could not be predicted theoretically. Increasing R_2 for values of R_3 less than 180Ω shows no sign of balance, nor would one be expected. Although it was not possible to verify (because the necessary supply voltage was not avaliable) it would be expected that for values of R_3 above 180Ω the circuit could be balanced at the rated heater current by increasing R_2 in accordance with Equation (22).

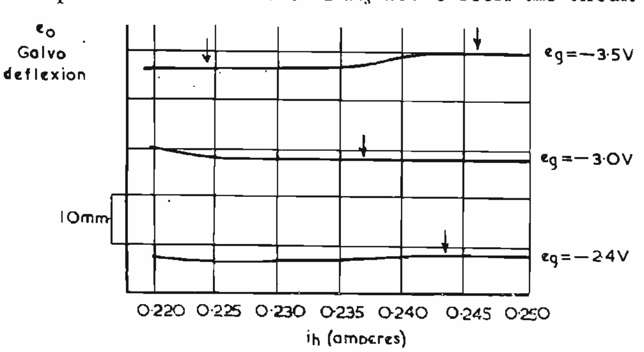

Fig. 8. Caldwell circuit—variation of balance point with control grid potential (the vertical separation of the curves is arbitrary)
R_c = 24.5Ω, R_1 = 12.7Ω, R_2 = O, R_3 = 180 Ω, R_s = 33.3kΩ, R_{na} = 225.4kΩ

Fig. 8 shows the $e_o - i_h$ curves for three different values of control grid potential at $R_3 = 180\Omega$ (the minimum value). Two balance points occur on each of the upper and lower curves, and if the supply voltage had been available, no doubt these points would have moved together at the value of $R_3 = 500\Omega$, predicted from Equation (23).

No investigation was made of the effect on the balance point of varying R_s, but Caldwell has shown that a shift can be obtained in this way. As in the Barth circuit no balance exists either theoretically or experimentally when $R_c = O$. The remarks made about varying R_4 in that circuit apply to R_s in the Caldwell circuit.

Conclusion

It may be said that a theoretical investigation on the lines set out in the preceding pages will prove a useful preliminary to the experimental use of an electrometer valve in a balanced circuit. Although this does involve the measurement of valve characteristics not normally supplied by the makers, a certain amount of labour may be saved on circuit adjustment in later stages of the work. The limitations of this theoretical approach have already been stated, but the experimental data obtained on the BM4 A have indicated how much of the circuit behaviour can be predicted. Although only one particular BM4 A was tested in this way, there is no reason to suppose that it was not a representative sample of a production valve, as all characteristics were near the mean of the manufacturer's published figures. Thus the conclusion may be drawn that this type of valve should work satisfactorily in either circuit, under the recommended operating conditions. However the necessary supply voltage for balance may be rather high in the case of the Caldwell circuit. The inclusion of the resistance R_c, which can be varied within wide limits, offers a further parameter for circuit adjustment.

Acknowledgments

The author is indebted to Messrs. Ferranti for the information they have given about this valve, and for their permission to publish the above data.

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A New Acoustic Mill Feed Controller

Pulverized fuel for modern draught-fed furnaces and boilers is processed in what are known as "Tube Mills." Coal fed continuously into this type of mill is reduced to the consistency of the finest grade powder by the action of cascading steel balls within a rotating tube or drum. The efficiency of the mill is almost entirely dependent on the correct amount of raw coal being continuously maintained within the tube, and this calls for careful and continuous regulation of the coal feed.

Messrs. Standard Telephones and Cables Ltd. have designed an automatic controller for this purpose, consisting of a microphone, which is placed immediately beneath the drum. This is connected by cable to the main controller unit which is set up at any desired distance from the tube mill.

The output from the amplifier-filter stage of the controller is used to actuate a sensitive relay which provides through suitable heat coils and relay trains, a means of altering the speed of the feed motor or, alternatively, for manual control purposes, of actuating a suitable gauge to afford visual indication of the contents of the tube mill.

The Theory and Applications of D.C. RESTORING CIRCUITS (Part 2)

By D. A. Levell, B.Sc. (Hons.), Grad. I.E.E.*

Automatic Black Level Restoration of Video Signals

(a) GENERAL THEORY :

The video signals of a television transmission are suppressed for a number of lines between each frame. It is during this period that the frame synchronizing signals are transmitted and the frame flyback period of receivers occurs. The positive peaks of the transmitted signals correspond to black level during this period so that a positive clamping circuit acting during this period would clamp at black level. In order that the clamp shall not conduct on video signals it must be suitably gated.

The gate pulse fed onto the grid of the clamping valve

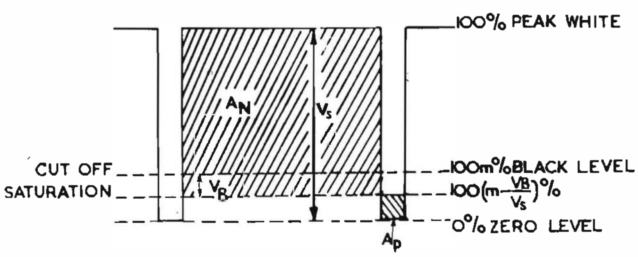


Fig. 15. Assumed operating conditions of a double limiter when designed for maximum rejection of noise modulation

may be suitably derived from the frame time base of the receiver. It is essentially a positive pulse which overrides a cut-off bias and switches the clamping valve on for a given period which is contained within the frame synchronizing period.

During the clamping period c charges through R_s and the valve to a potential corresponding to the black level of the video input signals E_s. At the end of the clamping period c either gains or loses charge until the beginning of the next clamping period. If c gains charge during this interval between clamping periods, the anode of the clamping valve will be negative during the next clamping period and black level restoration will not occur as the

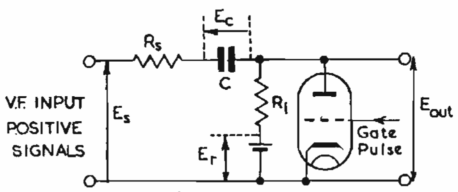


Fig. 16. Black level restoration circuit

clamping valve cannot conduct. However, if c loses charge during the interval between clamping periods, the anode of the clamping valve is taken positive at the start of the next clamping period and black level restoration will take place.

The essential condition for c to lose charge is,

$$E_r + E_c > E_{sm} \quad \ldots\ldots\ldots\ldots\ldots\ldots (37)$$

Where E_{sm} is the mean value of the video input taken over one whole frame period.

i.e., $E_r >$ the excess of E_{sm} above black level .... (38)

* *Messrs. A. C. Cossor Ltd.*

The maximum value of E_{sm} is approximately 90 per cent peak white, i.e., 0.9 E_p say, where E_p represents the amplitude of peak white. Therefore the maximum value of the excess of E_{sm} above black level is 0.6 E_p if the detector and video stages are linear, or 0.7 E_p if non linearity depresses the black level to 0.2 E_p. Thus, it is apparent that the minimum value of E_r should be chosen approximately equal to the amplitude of peak white of the video signals under normal operating conditions.

The choice of a minimum value for R_1 will now be considered.

Let E_b = black level of the input signal.
T_v = total off time of restorer during one frame.
T_s = total on time of restorer during one frame.

If restoration at black level is perfect the capacitor c is charged to the potential of the black level of the input, i.e., $E_c = E_b$. To obtain perfect restoration the ratio $R_1 : R_s$ is required to be infinitely high. When $R_1 : R_s$ is a finite quantity the capacitor will never be fully charged to the black level and at all times E_c will be less than E_b.

The difference potential between E_1 and E_b will be dependent upon the value of E_{sm} at any instant.

During T_v the potential driving charge through $R_s + R_1$, into c is $E_{sm} - E_r$. During T_s the potential driving charge through $R_s + R_a$ into c is E_b (assuming $R_a \ll R_1$).

Equation (38) states that $E_{sm} - E_r$ is less than or equal to E_b, so that for the purpose of determining the charge on c at any distant an equivalent circuit can be considered

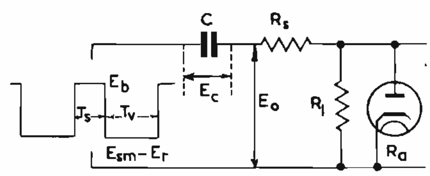


Fig. 17. Equivalent circuit of Fig. 16 referred to in the text

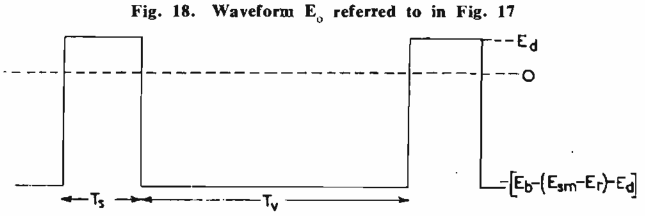
which consists of a simple restorer fed with a repetitive rectangular waveform of amplitude E_b for a period T_s and $E_{sm} - E_r$ for a period T_v as shown in Fig. 17.

Let E_d = the deviation of black level from zero output then the waveform E_o will be of the form shown in Fig. 18. The peak to peak amplitude of the waveform will be $E_b - (E_{sm} - E_r)$ so that if the positive peak is E_d referred to zero output the negative peak will be $-[E_b-(E_{sm}-E_r)-E_d]$.

Hence, applying the general theorem of Equation (6).

$$\frac{R_s + R_a}{R_s + R_1} = T_s/T_v \cdot \frac{E_d}{E_b - (E_{sm} - E_r) - E_d} \ldots\ldots (39)$$

Fig. 18. Waveform E_o referred to in Fig. 17



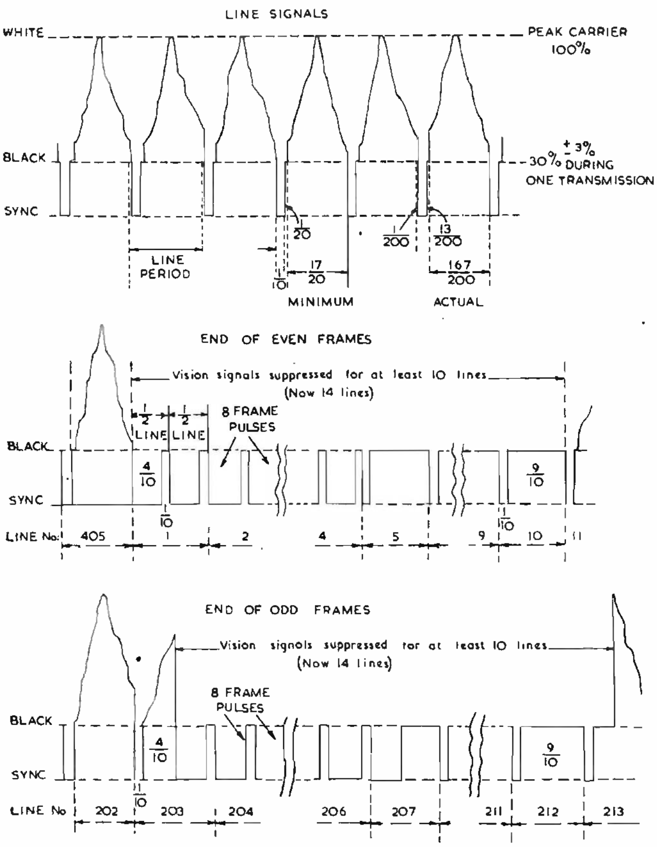


Fig. 19. Vision waveforms

Assume the value of E_b is $0.3\,E_p$ and $E_r = E_p$, then approximately, E_{sm} lies between $0.27\,E_p$ and $0.9\,E_p$ according to the picture content,

therefore, $E_b - E_{sm}$ lies between $0.03\,E_p$ and $-0.6\,E_p$

,, $E_b - (E_{sm} - E_r)$ lies between $1.03\,E_p$ and $0.4\,E_p$.

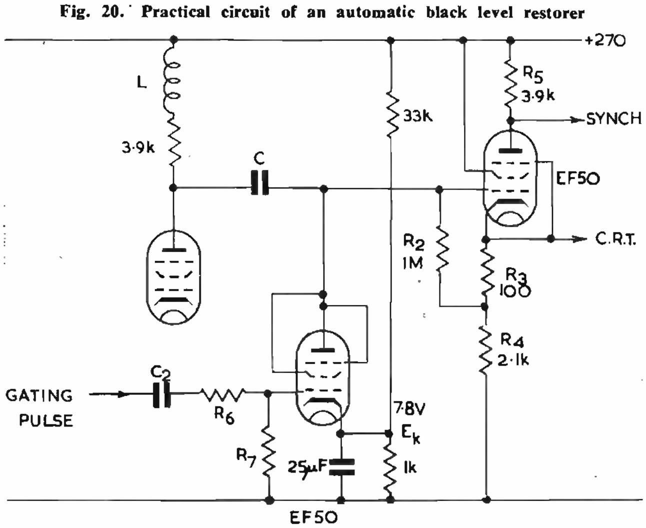
If it is considered that the maximum tolerable deviation of black level is 10 per cent of the video range (it follows from the equation,

$$\frac{\text{Fluctuation of picture level}}{\text{peak white} - \text{black level}} = \frac{E_d}{0.7\,E_p} \quad \ldots\ldots\ldots \quad (40)$$

that the following limiting equation must be obeyed,

$$E_d \leqslant 0.07\,E_p \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (41)$$

Fig. 20. Practical circuit of an automatic black level restorer



When E_d is at the maximum value of $0.07\,E_p$ the value of $\frac{R_s + R_1}{R_s + R_a}$ will be at a minimum and will lie between

$$\left(\frac{0.4}{0.07} - 1\right) T_v/T_s \text{ and } \left(\frac{1.03}{0.07} - 1\right) T_v/T_s$$

according to the picture content. Since restoration must be independent of the picture content, the minimum value of $\frac{R_s + R_1}{R_s + R_a}$ must be chosen to be the larger of these two quantities, so that the design equation to be satisfied is,

$$\frac{R_s + R_1}{R_s + R_a} \geqslant \left(\frac{1.03}{0.07} - 1\right) T_v/T_s \quad \ldots\ldots \quad (42)$$

i.e.,

$$\frac{R_s + R_1}{R_s + R_a} \geqslant 14\ T_v/T_s \quad \ldots\ldots\ldots\ldots\ldots \quad (43)$$

If it were possible to design the gating circuit to gate all of the 14 lines between frames (see Fig. 19) the value of T_s would be 980μS and value of T_v would be 19mS approximately, so the Equation (43) becomes,

$$\frac{R_s + R_1}{R_s + R_a} \geqslant 270 \quad \ldots\ldots\ldots\ldots\ldots \quad (44)$$

However, in a simple practical circuit in which the gating pulse is derived from the frame time base not more than lines 2 to 11 inclusive of Fig. 19 can be conveniently gated so that T_s is reduced to 710μS and the required minimum resistance ratio is increased to 370:1.

If the D.C. restoring valve is a triode connected EF50 or CV138 the value of R_a will be approximately 10k ohms if the grid is driven to cathode potential during T_s. A probable value of R_s is 3.9k ohms, so that if a minimum resistance ratio of 370 is required it is seen that R_1 must be

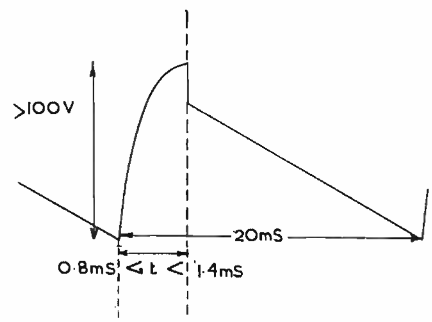


Fig. 21. A typical waveform present at the anode of a frame time base output valve

greater than 5.2M ohms. Since the specifications for most cathode-ray tubes and video amplifiers call for the grid-cathode path resistance to be not more than 1M ohm it is quite apparent that an automatic black level restoring circuit cannot conveniently be used to drive a video amplifier or cathode-ray tube directly. A cathode follower buffer stage must be used between the restorer and cathode-ray tube to obtain the required high value of R_1.

The minimum value of the coupling capacitor c will now be found by considering the waveform E_o depicted in Fig. 18. This waveform will no longer be rectangular when c is finite. During T_v the potential across the capacitor will change by the amount $T_v/CR_1 \cdot [E_b - (E_{sm} - E_r) - E_d]$ approximately, when $T_v < CR_1$. This change represents a drift of black level during a frame. The maximum amplitude of this drift which can be tolerated is approximately $0.05\,E_p$. The maximum value of $E_b - (E_{sm} - E_r) - E_d$ is $1.03\,E_p$ when E_d is negligible so that the minimum value of c is given by the design equation,

$$CR_1 \geqslant 20\,T_v \quad \ldots\ldots\ldots\ldots\ldots \quad (45)$$

i.e.,

$$CR_1 \geqslant 400\text{ mS} \quad \ldots\ldots\ldots\ldots\ldots \quad (46)$$

Hence, if the effective input impedance of the cathode follower is 10M ohms a coupling capacitor of 0.05 μF is required.

(b) Practical Circuit

The practical circuit of the automatic black level restorer given in Fig. 20 will now be considered in detail. In this circuit the cathode follower and clamping valve are triode connected EF50s. The cathode load resistor $R3+R4$ is chosen to be 2.2k ohms as this is the minimum value across which sufficient voltage swing can be

Fig. 22. Effect of passing the waveform in Fig. 21 through a 2mS differentiator coupling

developed to feed the cathode-ray tube, $R4$ is chosen at a minimum value in order to secure maximum gain to the synchronizing output. $R5$ is limited to 3.9k ohms by frequency response considerations. $R2$ is limited to 1M ohm to avoid effects of grid emission currents. Under these conditions the gain between grid-cathode and cathode-earth of the cathode follower stage is approximately 10. The effective input resistance of the cathode follower stage is thus 10M ohms approximately. The cathode of the clamping valve cannot be returned to earth or the circuit will clamp to zero the black level of the waveform at the grid of the cathode follower; synchronizing pulses would then be clipped by the cathode follower valve. The cathode of the clamping valve is therefore returned to a point of constant potential E_k which is derived from a potentiometer network across the H.T. supply. The value of $R3$ is chosen so that when the clamping valve is removed and no signals are present the potentials on the cathode follower circuit apply to the conditions of peak white. An EF50 valve is rated at a maximum cathode current of 15 mA. Approximately one-quarter of this current flows to the screen. The maximum anode and screen wattages are 3W and 1.7W. It can be shown that on an all-white picture the mean level over one whole frame is approximately 85 per cent of peak white, so that a limiting current of 17.6 mA can be taken to correspond to peak white. Table 1 gives suitable operating conditions for the cathode follower based on these limits.

the frame time base to avoid using extra valves. When the frame flyback period is longer than 800μS the required gating pulse is simply derived by differentiating the negative-going sawtooth usually present at the anode of the frame output valve. This sawtooth is usually greater than 100V in amplitude and often contains a positive pulse during the frame flyback, as shown in Fig. 21. If this waveform is passed through a 2 mS time constant a positive pulse of amplitude greater than 10V will generally be obtained as shown in Fig. 22. This waveform can be fed on to the grid of the clamping valve as shown in Fig. 20. Suitable coupling components being $C2=0.01$ μF, $R7=$ 220k ohms, $R6$ = 47k ohms.

Many frame circuits have a flyback time of less than 800μS. It is then necessary to choose the coupling components from the anode of the frame output valve, so that the clamp valve is switched on for a longer period than the frame flyback. This can be done by coupling the waveform through a long time constant of $c_2 = 0.1$ μF, $R7 =$ 4.7M ohms and then choosing $R6$ by experiment until the required on time of the clamp valve is obtained. This method depends upon partial D.C. restoration of the waveform on the grid of the clamp valve; the action will be made obvious by considering the equivalent restored waveform E_0 driving into the clamp valve grid circuit shown in Fig. 23.

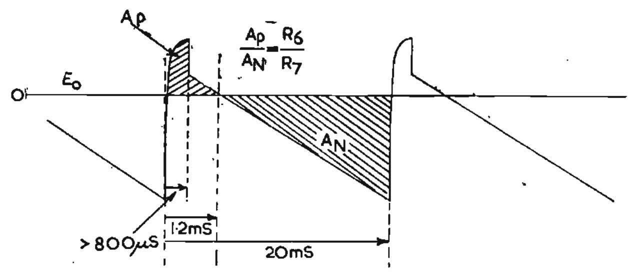


Fig. 23. Equivalent waveform E_0 obtained when the anode waveform of a short flyback frame time base is passed onto the clamp valve grid via a resistance ratio R6 : R7 of Fig. 20

(d) Advantages of Automatic Black Level Control

Variation of the R.F. gain control on a zero clamped television receiver increases both the black level and the contrast range. It is, therefore, necessary to adjust both brightness and R.F. gain controls together to set the picture levels correctly on a zero clamped system. If the receiver

	Grid to earth volts	Grid to cathode volts	Cathode current	Output across 2.2k load	Output referred to zero	Relative output	Output across 3.9k anode load
Peak white 100%	34.1	−1.6	16.3 mA	35.8 volts	34.3 volts	0%	0 volts
Black level 30%	7.8	−3.2	5.0 mA	11.0 volts	9.5 volts	28%	13.3 volts
Zero level 0%	−3.5	−5.0	0.7 mA	1.5 volts	0 volts	100%	47.7 volts

The required values of R3 and E_k are 100 ohms and 7.8 volts for the above conditions. The table is based on an H.T. supply of 270 volts. The output swing of 34.1 volts obtained is sufficient to fully drive most types of television cathode-ray tubes. The compression of synch. pulse amplitude from 30 per cent to 28 per cent is quite negligible. The negative going video output across $R5$ is of sufficient amplitude to drive a double slicer pentode type of synch. separator. The cathode-ray tube may, of course, also be driven from the anode load if cathode injection to the cathode-ray tube is required.

(c) Derivation of Gating Pulse

The best way of deriving the required gate pulse is to trigger a conventional phantastron or multivibrator delay circuit on the leading edge of the flyback of the receiver frame time base. The positive output pulse obtained from one of these circuits can then be fed on to the grid of the clamping triode. Although these circuits are easy to adjust, it may be preferred to use a waveform derived from

is fitted with automatic black level control, adjustment of the R.F. gain will only affect the contrast range, the black level setting being solely dependent upon the brightness control. Automatic black level control thus makes the brightness and R.F. gain control independent, and simplifies the setting up procedure.

Automatic black level control reduces the effect of aircraft flutter. Aircraft reflexions cause the amplitude of the received signals to fluctuate at a low frequency which depends upon the height, velocity and direction of flight of the aircraft. The effect is most disturbing to the eye when the fluctuation occurs at a few cycles per second. The fluctuation becomes negligible when the flutter frequency rises above 10 cycles per second. Let it be assumed that under certain conditions the low frequency flutter causes a fluctuation of $\pm$ m per cent in the overall amplitude of the video signal. Then if the amplitude of the video signal is 100 volts between zero and peak white it follows that for a zero clamped receiver, the peak white fluctuates by $\pm m$ volts and the black level fluctuates by $\pm 0.3m$ volts. If $CR1$ is taken to the minimum value of 400 mS to satisfy Equation (46) it is obvious that an automatic black level restoring circuit will follow fluctuations of the black level which occur at only a few cycles per second. It thus follows that if the same $\pm m$ per cent fluctuation occurs in a 100 volt video signal on a receiver fitted with automatic black level restoration the fluctuation of the black level is negligible and the fluctuation of the peak white level is $\pm 0.7m$ volts. It can be seen that these reductions are quite considerable.

Automatic gain control can easily be employed on a receiver fitted with automatic black level control. The amplitude of the negative peaks of a black level restored video signal will be directly proportional to the amplitude of the unmodulated carrier, so that if these peaks are rectified a negative voltage for A.G.C. is obtained. A suggested circuit for A.G.C. is given in Fig. 24. The use of automatic gain control with the automatic black level restoring circuit was suggested by A. H. A. Wynn.

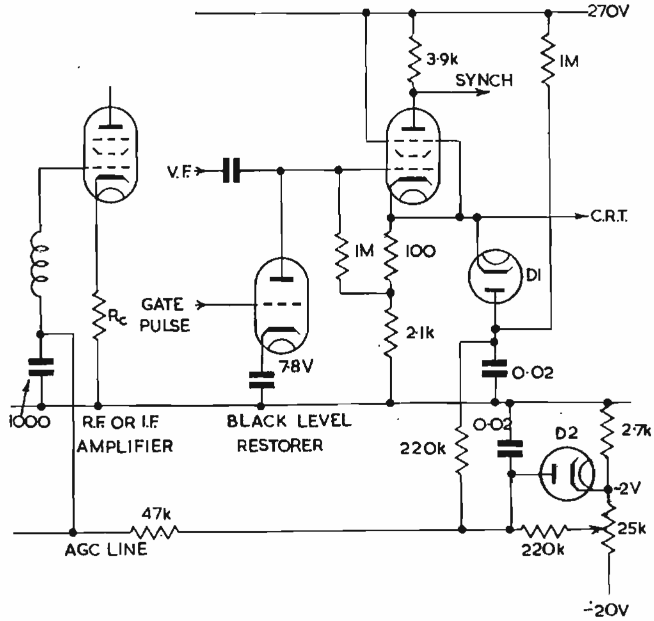


Fig. 24 (Right). Suggested circuit for applying A.G.C. to a television receiver. Diode D2 protects the receiver valves during the absence of signals. R_c stabilizes the input capacitance of the controlled stage

Economical Interlock and Indication Circuits

By D. B. Corbyn, B.Sc.(Hons.), A.M.I.E.E.

WHEN several electrical equipments are interconnected it is sometimes desirable to ensure that power can only be supplied when all equipments are similarly adjusted, and (for example) have their switches all set to position "A," or all to position "B," but that the power supply shall be cut off if one or more apparatus is set differently from the remainder.

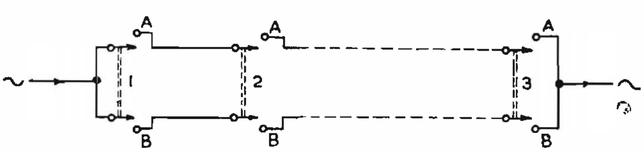


Fig. 1. Conventional two-position interlock (two switch poles used). Circuit is made only with "all A's" or "all B's"

The conventional interlock is shown in Fig. 1. This uses double-pole switches, and, although simple, is unnecessarily expensive. Occasions may arise when no more poles can be accommodated on the available switches so that this conventional interlock becomes unusuable.

The proposed circuit achieves the same object, but uses only single-pole two-position switches. The basic principle is illustrated in Figs. 2(a) and 2(b). Fig. 2(a) is

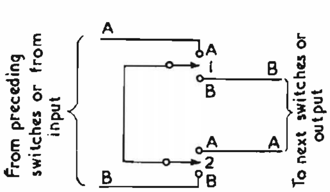


Fig. 2(a). Basic arrangement of two switches (single pole switches used)

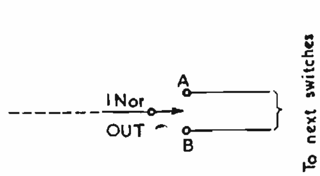


Fig. 2(b). End switch when total number of switches is odd (single pole switch)

the basic arrangement for any two switches and the arrangement of Fig. 2(b) is only required for the first (or last) equipment when the number of switches is odd.

Figures 3 and 4 show typical examples of three and four switches respectively with the interlock built from the basic circuits of Figs. 2(a) and 2(b).

In all cases it can be seen that the circuit is only complete for "All A's" or "All B's."

Extension of Principle

It is possible to interlock four positions with a single-pole four-position switch provided the positions are

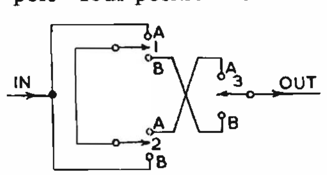


Fig. 3. Interlocking of three switches

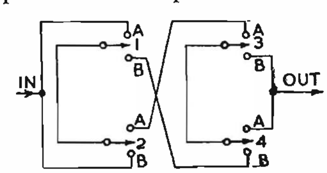


Fig. 4. Interlocking of four switches

grouped in two pairs with a separate isolated power supply for each pair.

Three positions can be interlocked in this manner by using rectifiers as shown in Fig. 5. Note that a rectifier is optional in position B and that only one is required for this position.

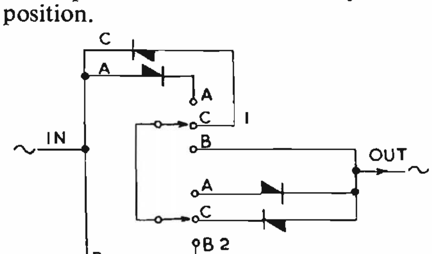


Fig. 5. Single pole interlock for two switches having three positions. Rectifiers are not essential for ensuring correct indication in position B

The system can be extended to any number of switches in a manner exactly comparable to that used for two-position indication. Three positions can also be interlocked by using two sources of isolated power supply.

THE COMPTON ELECTRONE

By Alan Douglas

The console, generator rack and loudspeaker cabinet of the Compton Electrone

THERE is one unique feature of this electronic organ; it is the only instrument using electrical tonal synthesis which is designed and made by a firm currently building pipe organs. One would therefore expect a high degree of tonal fidelity, allied to considerable refinement in control mechanism. Such all-important matters as touch and comfort in playing follow from the long experience of the builders, backed by a high tradition of craftsmanship. It is important to appreciate that this instrument is an *alternative* to the medium sized pipe organ and is made to last as long.

Most of the major problems with which the designer of any electronic organ is faced are bound up with the tonal fidelity expected. To provide an orthodox tonal scheme, it should be possible to segregate odd or even harmonics at will, correctly represent tones in several octave pitches, and control the rate of attack and decay. Whereas with some methods these fundamental requirements can only be met by complex means, if at all, in this instrument all these features can be easily and economically incorporated.

There are two standard types of Electrone, each comprising a playing desk of two manuals and pedal. Larger three-manual instruments have also been made to special order. Whilst the tonal content varies with the type, the principle is the same in all cases, and consequently the model 347 adequately represents the method.

The electrostatic generators consist essentially of 12 rotating variable capacitors, mechanically driven by means of an endless belt from a common motor. The pulleys are so dimensioned that each capacitor is driven at the correct speed, which increases in the ratio $1:\sqrt[12]{2}$ so as to produce the intervals of the tempered scale. This construction ensures that the organ will always be in perfect tune. Each generator consists of two stationary disks, with a scanning rotor in between them. Every disk carries a series of engravings representing the waveforms to be scanned, and the disks themselves are fitted in diecast metal casings mounted on ball bearings. By an ingenious arrangement the disks can be oscillated in their bearings, so as to produce a frequency modulated vibrato or tremulant.

Fig. 1 shows an engraved stator disk and the form of the web-like rotating scanner. The electrodes on the disk are formed by coating a Bakelite blank with a film of metal about 0.002in. thick. On a special engraving machine, a fine groove is cut corresponding to the required waveform, and forms a complete circle. Either a circle or similar wave form is then cut adjacent to the first one, resulting in an annular ring of metal of undulating width. The whole surface of the disk is thus subdivided into a number of rings, some of which are the waveforms proper, and some the earthed margins separating them. The number of complete waves in the various rings determines the pitch of the notes, and each ring has an external connexion taken out to the insulated back of the disk by means of a pin passing through the material.

The actual contours of the waveform vary; some consist of an integrated series of even harmonics, some consist of many odd harmonics; some only a few odd harmonics. Others may be simple waveforms, whilst yet others may be completely pre-formed waves. There are, on the average, 20 to 30 rings of waveforms per generator assembly, and harmonics up to the 30th are available for tonal synthesis. The waveforms for the lowest frequencies are separately connected to the external circuits.

The rotating scanning member is diecast in metal, and takes the form of a number of conductive radial ribs arranged like a spider's web. The number of scanning elements varies with the number of separate waves on the track it has to scan. This is clearly seen from Fig. 1. The accuracy of scan is determined by the width of the webs, and the signal level by the number of ribs. A valuable feature is that any slight inaccuracy which may have crept into the engraving is cancelled out by the opposing pairs of webs at any instant of scan: this same feature also equalizes any slight change in air gap.

The manufacture of these items calls for great care and close tolerances and is most admirably carried out. In spite of the high speed of some of the scanners, the generator is completely silent.

Now in the case of a single ring electrode, it will be seen that the capacitance between it and the rotor will be greatest when the radial lines of the rotor coincide with the widest parts of the curve, and least opposite the narrow parts. The capacitance therefore varies in a continuous and cyclic manner as the rotor revolves. If there is no polarizing potential applied to the rings, no A.C. potential can exist even if the rotor is moving; but if a potential is applied, then an A.C. voltage will be developed corresponding to the variations in capacitance, which, of course, means that this potential will be an exact replica of the engraved waveform.

Fig. 2 shows one electrode A with a polarizing circuit connected to it; this is the stator. The rotor is connected to an amplifier. The capacitor C bypasses any A.C. component which may try to return through the D.C. polarizing network, and together with R forms a time-delay circuit so that the build-up of the charge on A may be controlled; it also serves to remove objectionable transients which would appear if the full polarizing voltage were suddenly applied. When the key G is open, the resistor E keeps the electrode at earth potential. Capacitor F also modifies the time constant of the circuit, especially the decay; there may also be additional external circuits to produce special time/amplitude effects When G is closed, current from the D.C. source H charges F, C and A. D may, for instance, be 1 megohm and C 0.001μF; F may be 0.01μF, but for very long time delays it may be up to 1.0μF, depending on the rate of leakage through E. Fig. 3 shows the equivalent electrical circuit where Z is a zero impedance generator. Y is the stator-to-rotor capacitance of one speaking note, and X is the shunt capacitance of all the other chargeable electrodes together with that of all the earthed areas separating the various rings. The input impedance of the amplifier is indicated by R.

There is an important point in design here; the waveform of the earthed rings is the inverse of the waveform proper. From grid to earth, therefore, the capacitance is constant at all times irrespective of whether a signal ring is in use or not. Thus each earthed ring acts as a differential capacitance to the ring to which it is adjacent. If an electrode were, for instance, standing proud with no earthed rings, the grid-to-earth capacitance would vary as the sum of all the other waveform capacitances, resulting in modulation. For example, if a high note were sounding (small capacitance), then the comparatively large changes in shunt load due to a bass note (large capacitance) would modulate the high note.

It might be stated that there are other methods of connecting such generators, but in general they result in frequency discrimination, noise and loss of signal strength.

In playing an organ of this circuit type by normal methods, many frequencies will coincide when played from different note keys on the same or other keyboards simultaneously. For instance, a second harmonic coincides exactly with the fundamental pitch of one octave higher. It is therefore necessary to provide an electrical network which will allow the same ring electrode to be polarized from many different contacts without interaction with each other, and at the same time to ensure that when two or more are operated together, the tonal increments will follow the correct loudness law.

Fig. 4 shows the circuit for this purpose, the electrode arrangement being as just described. The contacts at each point of the keyboard at which the particular note is required are shown at G, and each can make contact with a busbar M. According to the setting of the stops, these busbars may be at any potential from zero to about 400V. At each contact point there are two resistors, K and L, usually of equal value and of the order of 2 megohms. Under these conditions, if two busbars are at equal voltage, so that depression of either contact would sound the note at the same strength, the note should increase by 3db when both contacts are closed together. If four contacts are simultaneously closed, the voltage will roughly be double, resulting in an increase of 6db. This ability to compensate for keying additional notes in a common generator system is extremely valuable, completely overcoming one of the prinicpal disadvantages of such systems; it should be noted that the method is only applicable to electrostatic generators, except under special circumstances which introduce much complexity.

The tone-colours are formed by adjustment of the relative potentials on the various rings. The busbars are common to all keys on any manual, and each is associated with one tonal quality. Suppose that only one ring is raised in potential; then the playing keys will only apply voltages to rings appropriate to that harmonic, all the remaining busbars being at zero potential. Each stop is arranged to raise any combination of bars to any potential, and it is by this means that most of the tonal qualities of the instrument are set up.

Fig. 5 shows the stop circuit in essence. Each busbar

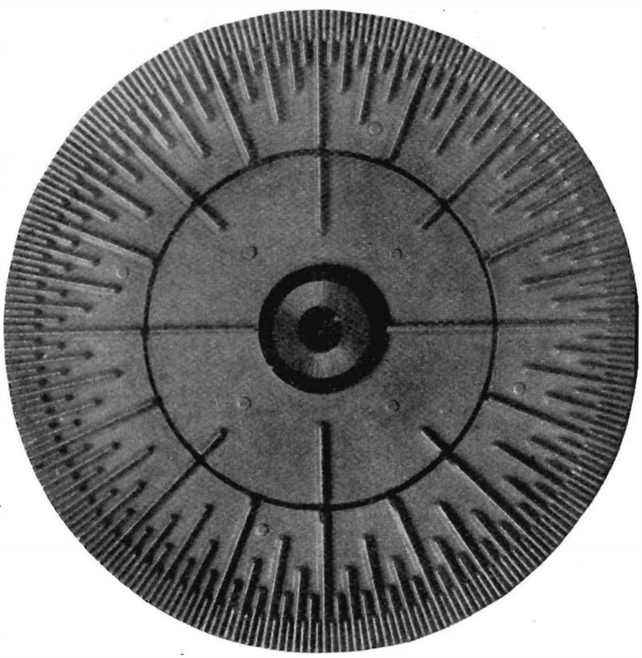


Fig. 1A. Rotating scanner

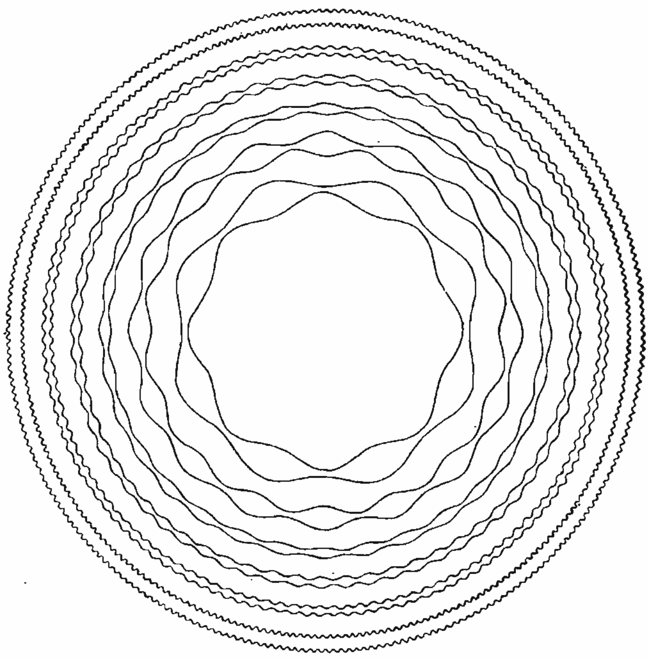


Fig. 1B. Engraved stator disk

is connected to the main H.T. supply through resistors *B* via the leads *A*1, *A*2, *A*3, etc. Each stop controls as many contacts as are necessary for the harmonic development of that particular tone-colour. The figure shows two stops, *S*1 and *S*2. Between each contact and the H.T. source are resistors *C*. The values of these units are so chosen that the busbars are raised to the correct relative values when the stop is operated.

Recent research has shown that greater realizm in additive synthesis can be obtained if groups of suitable waveforms are added, rather than the direct combination of simple pure waves. It is well known that the majority of orchestral instruments, and practically all organ pipes, owe their marked individuality to bands of fixed frequencies which are to a great extent a function of the resonant properties and rate of sound transmission in the particular materials of which the sound producer is made. These bands of frequencies are known as formants, and are substantially the same for all notes in the characteristic tonal part of the range of the particular instrument. The magnitude of the formant band increases with the complexity of the tone, but does not extend over a range of notes outside the normal compass of the instrument. For example, the formant band in a trumpet can be clearly heard if a soft mop is tightly inserted into the bell of the instrument. Most of the fundamentals are damped out, that is, the major resonances of the metal tube and the air column, but the formant group remains and can clearly be heard as a tone something like the familiar "paper comb." If the frequency band forming this complex tone is added to a fundamental and possibly other frequencies, a very realistic trumpet results.

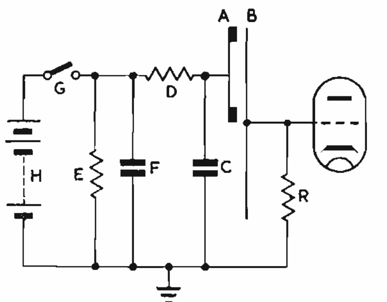


Fig. 2. Input and polarizing circuit

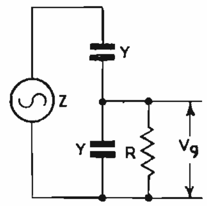


Fig. 3. Equivalent circuit of Fig. 2

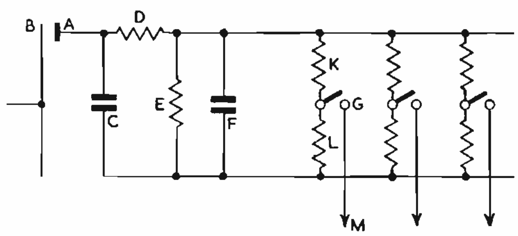


Fig. 4. Circuit of electrical network for different polarizing voltages

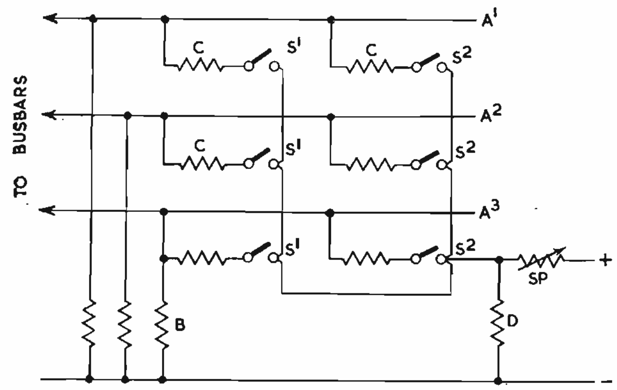


Fig. 5. Stop circuit

Volume control is effected by means of the variable resistor *SP*, operated by a balanced swell pedal; this is part of a potential divider, *SP/D*, connected across the main H.T. supply line, thus varying the polarizing voltages to the system.

One of the outstanding advantages of the electrostatic method of tone generation is that all keying is done in the D.C. lines, and hence the signal circuits are not interrupted or taken out of the shortest route to the amplifying equipment. This enables a perfectly standard pipe organ console to be used with its normal key and stop contacts, pistons and magnetically indicating self-cancelling stop keys. Consequently there is no electronic apparatus whatever in the console, which may be placed wherever convenient.

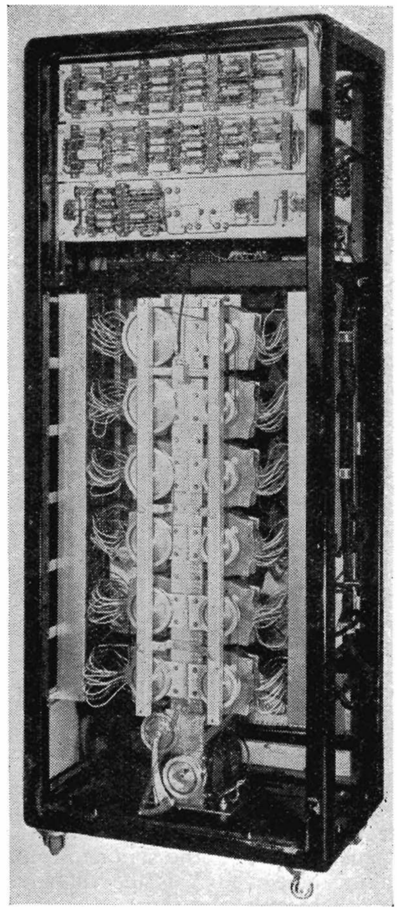


Fig. 6. Rear view of apparatus rack showing two rows of six belt-driven generators

The control of the many mixing circuits is carried out by relays of pipe organ design, which are enclosed and the contacts thus protected; they are immediately behind the generator disks in Fig. 6, which shows the complete generator, amplifier and power supply unit.

The tone quality of this instrument is strikingly beautiful, being liquid and persuasive, yet possessing drive and "bite" when called upon. So much attention has been given to the subtractive type of organ that it is a pleasure to draw attention to the obvious merits of this highly-developed additive system which is based on the original inventions of Mr. L. E. A. Bourn.

THE ASSEMBLY AND TESTING of G.E.C. Cathode Ray Tubes

THE Osram-G.E.C. Cathode Ray Tube Works at Perivale, Middlesex, was built in 1942 for the Ministry of Aircraft Production. Early in 1950 the G.E.C. took over the building for the modernized manufacture of cathode ray tubes.

The glass bulbs for the tubes are made in the G.E.C. Glassworks at Lemington-on-Tyne and the various components for the "gun" assemblies are produced on high speed tools at Hammersmith. At Perivale the assembly of the complete tubes takes place.

The following description outlines the main manufacturing operations from the point at which bulbs are received from the glassworks until the finished tubes are placed in store.

The glass is pressed into the typical television tube shape at the G.E.C. Glassworks, Lemington-on-Tyne. After a careful annealing treatment each bulb is pressure-tested with water applied externally at a difference in pressure of two atmospheres.

The finished bulbs are sent to the Perivale Works of the G.E.C. and are first given a most careful washing.

Washing the Bulbs

The washing process takes 20 minutes and is divided into six steps and takes place on a semi-automatic machine.

Applying the Screen

To enable the fluorescent powder to adhere firmly, a binder is applied to the internal face of the bulb and the material used is a solution of phosphoric acid in acetone.

A quantity of the binder is filtered into the bulb and the excess liquid is then drained off and partially dried. Next, a controlled amount of fluorescent powder, chiefly zinc sulphide, is placed in a glass air-gun and is sprayed uniformly over the sticky inner surface of the glass face of the bulb, after which the bulb is rotated in a machine and at the same time is tapped gently to free the excess powder. Finally the bulb is revolved and the entire inner surface, excepting the screen, is cleaned to remove unwanted powder.

After the powder has been applied, the bulb is placed in a rotary oven and given a 45-minute baking at a temperature of 350°C, to fuse the phosphoric acid binder. During baking, the evolved vapours are removed by blowing filtered air into the bulb.

Aluminizing

The first step is to fill the voids in the powder so that a reasonably uniform surface is presented and the way to the front of the grains blocked. This is done by washing the powder and then flooding it with water, the temperature of which has to be controlled within 1°C. Next, a small quantity of nitro-cellulose in a butyl alcohol/ether solution is dropped on to the surface of the water and is allowed to spread naturally. The water is then decanted slowly and the film settles down on to the powder.

Now follows the aluminizing operation in which the bulbs are mounted in a multi-head machine. At the end of the pumping operation a spiral of pure aluminium wire is vaporized electrically within the bulb and the metallic vapour condenses on the inner surface of the screen.

Electrode Assembly

Simultaneously with the processing of the bulb, the electrodes are assembled and this operation is one of extreme precision.

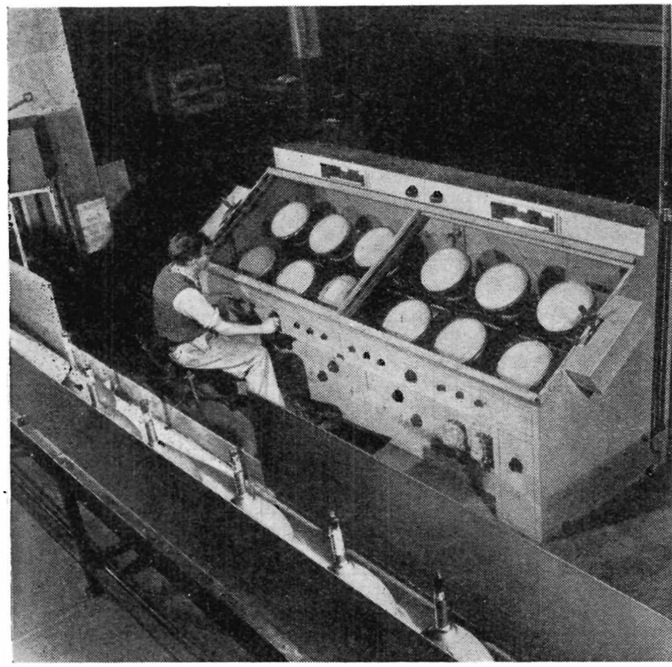
After the "gun" has been assembled it is checked electrically for continuity and insulation and is finally washed in alcohol.

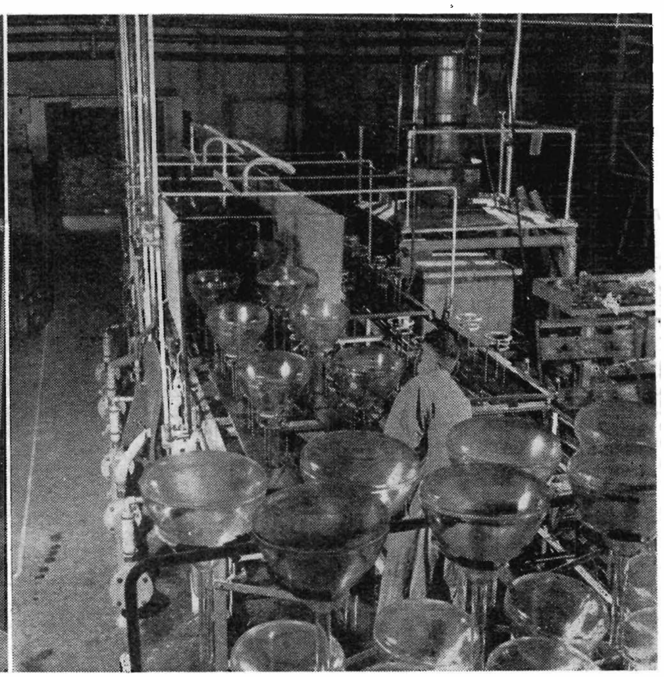
Ageing and Testing

In the ageing process which follows sealing and pumping an initial H.T. voltage of 2kV is applied to the anode and is slowly increased to 10kV over a period of 30 minutes. During this period the beam current is gradually increased and the screen is scanned to prevent "burning."

In addition, one tube in every ten is carefully checked for all characteristics and the results plotted statistically. The tubes are then stored in cartons for two weeks and at the end of this time every tube is again tested under "receiver" conditions, after which it is finally packed ready for despatch.

The photos show (Left) Ageing tests of the finished tubes. (Right) Washing the bulbs on a multi-stage automatic machine.





Relations Between Amplitudes of Harmonics and Intermodulation Frequencies

in the Output from a Non-linear Amplifier or Mixer

By M. V. Callendar, M.A., A.M.I.E.E. and S. Matthews

THE output from an amplifier (or mixer) is here calculated for the following conditions:—

Input voltage = $V_1 \cos \omega_1 t + V_2 \cos \omega_2 t$

Amplifier characteristic defined by:

$$I = aV + bV^2 + cV^3 + dV^4 + eV^5 + fV^6$$

The relative amplitudes of the various harmonics and intermodulation frequencies are calculated and tabulated for the general case where V_1 and V_2 are unequal.

Tables are also given for the simpler special cases where $V_1 = V_2$ and where $V_2 = 0$: in the latter case, additional terms gV^7 and hV^8 are included.

Practical applications include the estimation of unwanted outputs from high frequency mixing systems (i.e., as used in so-called "synthesizer" circuits) and of distortion from audio-frequency amplifiers. Some conclusions upon the value of intermodulation tests for audio-frequency amplifiers also emerge.

The results will apply to push-pull or push-push mixers or "amplifiers" as well as to single valves: in these cases the even or odd power coefficients respectively will approximate to zero.

However, the conclusions must be applied with caution in any practical case, since it appears that in many amplifier characteristics the terms are not strongly convergent, and a longer series would be required to represent them adequately.

Calculations

We put $V = V_1 \cos \omega_1 t + V_2 \cos \omega_2 t$ in the formula for I; on expanding the terms in V^2, etc., by the binomial theorem, an expression in powers of $\cos \omega_1 t$ and $\cos \omega^2 t$ results; this is then transformed into an expression in terms of cosines of multiple angles (harmonics) and of cosines of sums or differences of multiple angles (intermodulation products).

Apart from the binomial theorem, the basic formulæ used are:

$$\cos A \,.\, \cos B = \tfrac{1}{2}[\cos(A - B) + \cos(A + B)]$$

$$\cos^2 A = \tfrac{1}{2}(1 + \cos 2A)$$

$$\cos^n A = 2/2^n \left[\cos nA + n.\cos(n-2)A + \frac{n(n-1)}{2\,!}\,.\cos(n-4)A + \text{etc.} \right]$$

TABLE 1.—OUTPUT OF D.C. AND HARMONIC FREQUENCIES FOR GENERAL CASE WHERE V_1 AND V_2 ARE UNEQUAL

Term	D.C.	Cos θ_1	Cos $2\theta_1$	Cos $3\theta_1$	Cos $4\theta_1$	Cos $5\theta_1$	Cos $6\theta_1$
$a\,V$		$a\,V_1$					
$b\,V^2$	$\frac{b}{2}\left[V_1^2+V_2^2\right]$		$\frac{b\,V_1^2}{2}$				
$c\,V^3$		$\frac{3c}{4}\left[2V_1V_2^2+V_1^3\right]$		$\frac{C}{4}V_1^3$			
$d\,V^4$	$\frac{3d}{8}\left[V_1^4+4V_1^2V_2^2\right]$		$\frac{4d}{8}\left[V_1^4+3V_1^2V_2^2\right]$		$\frac{d}{8}V_1^4$		
$e\,V^5$		$\frac{10e}{16}\left[V_1^5+3V_2^4V_1+6V_1^3V_2^2\right]$		$\frac{5e}{16}\left[V_1^5+4V_1^3V_2^2\right]$		$\frac{e}{16}V_1^5$	
$f\,V^6$	$\frac{10f}{32}\left[V_1^6+9V_1^4V_2^2+9V_1^2V_2^4\right]$		$\frac{15f}{32}\left[V_1^6+8V_1^4V_2^2+6V_1^2V_2^4\right]$		$\frac{6f}{32}\left[V_1^6+5V_1^4V_2^2\right]$		$\frac{f\,V_1^6}{32}$

The coefficients of Cos θ_2, Cos $2\theta_2$, etc., are the same as for Cos θ_1, Cos $2\theta_1$, etc., but with V_1 replaced by V_2.

In this and the other tables, θ_1 and θ_2 are written for $\omega_1 t$ and $\omega_2 t$.

TABLE 1a.—OUTPUT OF INTERMODULATION FREQUENCIES FOR GENERAL CASE WHERE V_1 AND V_2 ARE UNEQUAL

Term	H	J	K	L	M	N	O	P	R
$b\,V_2$	$b\,V_1V_2$								
$c\,V^3$		$\frac{3c}{4}V_1V_2^2$							
$d\,V^4$	$\frac{6d}{8}V_1V_2\left[V_1^2+V_2^2\right]$		$\frac{6d}{8}V_1^2V_2^2$	$\frac{4d}{8}V_1V_2^3$					
$e\,V^5$		$\frac{10e}{16}\left[2V_1V_2^4+3V_1^3V_2^2\right]$				$\frac{5e}{16}V_1V_2^4$	$\frac{10e}{16}V_1^2V_2^3$		
$f\,V^6$	$\frac{60f}{32}\left[V_1^5V_2+V_1V_2^5+3V_1^3V_2^3\right]$		$\frac{30f}{32}\left[V_1^4V_2^2+V_1^2V_2^4\right]$	$\frac{30f}{32}\left[V_1V_2^5+2V_1^3V_2^3\right]$	$\frac{20f}{32}V_1^3V_2^3$			$\frac{6f}{32}V_1V_2^5$	$\frac{15f}{32}V_1^2V_2^4$

H is the coefficient of $[\cos(\theta_1-\theta_2)+\cos(\theta_1+\theta_2)]$
J „ „ „ $[\cos(\theta_1-2\theta_2)+\cos(\theta_1+2\theta_2)]$
K „ „ „ $[\cos 2(\theta_1-\theta_2)+\cos 2(\theta_1+\theta_2)]$
L is the coefficient of $[\cos(\theta_1-3\theta_2)+\cos(\theta_1+3\theta_2)]$
M „ „ „ $[\cos 3(\theta_1-\theta_2)+\cos 3(\theta_1+\theta_2)]$
N „ „ „ $[\cos(\theta_1-4\theta_2)+\cos(\theta_1+4\theta_2)]$
O is the coefficient of $[\cos(2\theta_1-3\theta_2)+\cos(2\theta_1+3\theta_2)]$
P „ „ „ $[\cos(\theta_1-5\theta_2)+\cos(1\theta_1+5\theta_2)]$
R „ „ „ $[\cos(2\theta-4\theta_2)+\cos(2\theta_1+4\theta_2)]$

N.B.—The output also contains terms with coefficients J[1], L[1], N[1], O[1], P[1], and R[1] in which V_2 takes the place of V_1 and θ_2 of θ_1.

TABLE 2.—OUTPUT OF HARMONIC AND INTERMODULATION FREQUENCIES FOR SPECIAL CASE WHERE $V_1 = V_2 = V$

Term	D.C.	Cos θ_1	Cos $2\theta_1$	Cos $3\theta_1$	Cos $4\theta_1$	Cos $5\theta_1$	Cos $6\theta_1$	H	J	K	L	M
aV		Va										
bV^2	V^2b		$\frac{V^2b}{2}$					V^2b				
cV^3		$\frac{9V^3c}{4}$		$\frac{V^3c}{4}$					$\frac{3V^3c}{4}$			
dV^4	$\frac{15V^4d}{8}$		$\frac{16V^4d}{8}$		$\frac{V^4d}{8}$			$\frac{24V^4d}{8}$		$\frac{6V^4d}{8}$	$\frac{4V^4d}{8}$	
eV^5		$\frac{100V^5e}{16}$		$\frac{25V^5e}{16}$		$\frac{V^5e}{16}$			$\frac{50V^5e}{16}$			
fV^6	$\frac{190V^6f}{32}$		$\frac{225V^6f}{32}$		$\frac{36V^6f}{32}$		$\frac{V^6f}{32}$	$\frac{300V^6f}{32}$		$\frac{60V^6f}{32}$	$\frac{90V^6f}{32}$	$\frac{20V^6f}{32}$

For the meaning of H, J, K, L and M, see Table 1a.
The above table omits two high order intermodulation products of eV^5 and two or fV^6: for these, see Table 1a.

where terms in cosines of negative angles are neglected and cos. $(0 \times A)$ is taken as $1/2$.

The actual working out is far too lengthy to be reproduced here, but the coefficients of all the terms in the output are concisely tabulated in Tables 1 and 1a.

The special case where $V_1 = V_2$ yields much simpler expressions, as tabulated in Table 2, and results for the simplest case, where $V_2 = 0$, are given in Table 3, where two extra terms, gV^7 and hV^8 have been included.

The expressions are symmetrical with respect to V_1 and V_2, and ω_1 *and* ω_2, and thus the tabulation of only about half the coefficients affords all the information required. In the Tables, θ_1 and θ_2 have been written for $\omega_1 t$ and $\omega_2 t$ for convenience.

Discussion and Conclusions

A number of unexpected conclusions emerge from an inspection of the Tables.

It must be remembered, however, that these conclusions only apply strictly for the relatively simple amplifier characteristic assumed. Cases where any discontinuity occurs (e.g. where grid current is present) can only be treated by entirely different analytical methods, involving Fourier series.

1. In all cases, even with only a single input ($V_2 = 0$), the amount of n^{th} harmonic produced by the term in V^n in the characteristic is much less than the amounts of lower harmonics produced by the same term.

For example, if the coefficient (f) of the term in V^6 is sufficient to produce 1 per cent of 6th harmonic with a single input, this term will produce 6 per cent of 4th harmonic and 15 per cent of 2nd harmonic. It is seen from Table 3 that these figures for relative amplitude form a series identical to the binominal coefficients of the same order.

2. Where there are two inputs, the amplitudes of the inter-modulation products originating from a term in V^n are much larger than the amplitude of the n^{th} harmonic.

For example, if $V_1 = V_2$ and the term in V^6 produces 0.1 per cent of 6th harmonic, it will produce also 30 per cent, 6 per cent, 18 per cent, 2 per cent, 1.2 per cent and 3.0 per cent respectively of the six types of intermodulation product (actually 18 different frequencies in all). Note, however, that the sum of the amplitudes of the inter-modulation products originating from a term in V^n is not much larger than the sum of the harmonics originating from the same term (e.g., 22 per cent of 2nd and 3.6 per cent of 4th harmonic are produced in the case quoted).

3. When a second input V_2 is added to an amplifier already supplied with V_1, the output of the lower harmonics of V_1 is in general greatly altered if the characteristic has high power terms of any appreciable magnitude.

For example, if the term fV^6 produced 0.1 per cent of 6th harmonic with V_1 only applied, an extra 3 per cent of 4th and 21 per cent of 2nd harmonic will appear in the output when the other input V_2 is switched on, in the case where $V_2 = V_1$. A similar increase in harmonics is, of course, also produced by an increase of V_1.

4. Provided that the amplifier characteristics is free from discontinuities (e.g. as sometimes caused by grid current), and is describable by a power series whose coefficients converge with reasonable rapidity, it is evident from 1, 2 and 3 above that lower harmonics will in general be much larger than higher ones. Conversely, we may say, that any at all large percentage of higher harmonics can only be caused by a virtual discontinuity in the characteristic.

Thus, the amount of 8th harmonic from a single tone applied to a characteristic not having any 10th or higher order terms cannot much exceed 1 per cent, since the amplitude of 2nd harmonic generated from a single tone is 56 times that of the 8th harmonic.

This can also be seen by considering relative magnitudes of the terms in the amplifier characteristic: the term hV^8 is unlikely to be greater than the term aV, and this corre-

TABLE 3.—OUTPUT FOR SPECIAL CASE WHERE $V_2 = O$ $V_1 = V$

Term	D.C.	Cos θ_1	Cos $2\theta_1$	Cos $3\theta_1$	Cos $4\theta_1$	Cos $5\theta_1$	Cos $6\theta_1$	Cos $7\theta_1$	Cos $8\theta_1$
aV		Va							
bV^2	$\frac{V^2b}{2}$		$\frac{V^2b}{2}$						
cV^3		$\frac{3V^3c}{4}$		$\frac{V^3c}{4}$					
dV^4	$\frac{3V^4d}{8}$		$\frac{4V^4d}{8}$		$\frac{V^4d}{8}$				
eV^5		$\frac{10V^5e}{16}$		$\frac{5V^5e}{16}$		$\frac{V^5e}{16}$			
fV^6	$\frac{10V^6f}{32}$		$\frac{15V^6f}{32}$		$\frac{6V^6f}{32}$		$\frac{V^6f}{32}$		
gV^7		$\frac{35V^7g}{64}$		$\frac{21V^7g}{64}$		$\frac{7V^7g}{64}$		$\frac{V^7g}{64}$	
hV^8	$\frac{35V^8h}{128}$		$\frac{56V^8h}{128}$		$\frac{28V^8h}{128}$		$\frac{8V^8h}{128}$		$\frac{V^8h}{128}$

sponds (see Table 3) to a limit of 0.8 per cent for 8th harmonic. Corresponding likely maxima for other harmonics are 1.6 per cent of 7th, 3.2 per cent of 6th and so on.

5. If a *mixer* is to be used, as normally, to provide a wanted output of first order difference (or sum) frequency $(f_1 \pm f_2)$, the unwanted output of harmonics and intermodulation frequencies of higher order can be reduced by—

(a) using a characteristic as nearly square law as possible.

(b) reducing both inputs.

6. As regards *audio distortion*, if the first order sum or difference tone $(f_1 \pm f_2)$ only is measured, this will not take into account the distorting effect of odd power terms in the characteristic: this test would, for instance, show zero distortion for a well balanced push-pull stage. It does not even necessarily take any more account of the presence of high order terms in the characteristic than does a measurement of second harmonic; from Table IV we see that high order curvature notably affects the per cent of the sum tone only when V_1 and V_2 are of the same order, and that a very similar effect occurs with the 2nd harmonic with *two* inputs.

However, it remains true that a measurement of the $(f_1 \pm f_2)$ and the $(f_1 \pm 2f_2)$ tones, with $V_1 = V_2$, will show up high order distortion much better than the conventional test for 2nd and 3rd (or for total) harmonic with a single input.

TABLE 4, OUTPUT OF 2nd HARMONIC AND OF SIMPLE SUM (OR DIFFERENCE) FREQUENCIES COMPARED, ASSUMING TOTAL PEAK VOLTS APPLIED = V_0 IN ALL CASES

TERM OF ORIGIN	2nd HARMONIC		SUM FREQUENCY (H)	
	For $V_1 = V_0$, $V_2 = 0$	For $V_2 = V_1 = 0.5V_0$	For $V_1 = 0.91V_0$, $V_2 = 0.09V_0$	For $V_2 = V_1 = 0.5V_0$
bV^2	$\frac{bV_0^2}{2}$	$\frac{1}{4}.\frac{bV_0^2}{2}$	$\frac{1}{6}.\frac{bV_0^2}{2}$	$\frac{1}{2}.\frac{bV_0^2}{2}$
dV^4	$\frac{4dV_0^4}{8}$	$\frac{1}{4}.\frac{4dV_0^4}{8}$	$\frac{1}{6}.\frac{5dV_0^4}{8}$	$\frac{1}{2}.\frac{3dV_0^4}{8}$
fV^6	$\frac{15fV_0^6}{32}$	$\frac{1}{4}.\frac{14fV_0^6}{32}$	$\frac{1}{8}.\frac{20fV_0^6}{32}$	$\frac{1}{2}.\frac{10fV_0^6}{32}$

A New Industrial Application Showroom

INDUSTRIAL machinery and manufacturing processes are so closely linked in modern industry that it has become essential for the industrialist not only to know that a machine can perform a certain function, but also that the process it employs is the most favourable for the manufacture of his particular commodity.

A mere display centre of machinery, especially if it is only concerned in putting over one system of approach, is therefore of little avail to him, and will neither show him the best way to overcome his production difficulty nor physically demonstrate why a certain process or machine is the most suitable.

The Philips Application Showroom, opened at Brixton on April 10, 1951, is conceived and realized on a much wider and more important basis. It is part of a compact and many sided team-work of laboratories and specialists all grouped around the site of, and in close liaison with, the showroom.

The industrialist can bring drawings or samples of the work he wants to do, discuss his problem with our design, research and production engineers, metallurgists and draughtsmen on the premises, and is then able to see his work carried out by a large number of different machines employing entirely different methods of treatment.

As an example, let us take the industrialist wishing to join a number of metal components in a certain manner. Metal can be joined by Arc Welding, Resistance Welding and H.F. Heating—and in most cases only one of these methods will prove to be the most efficient and economical.

He takes to the Philips Industrial Showroom drawings, and samples of the metal he wishes to use, and with a view to the many factors involved, i.e., the kind, thickness and proportions of the metal, factory space, economical rate of producing the article, etc., discusses with our specialist personnel the various machines and methods that can be used. He then proceeds into the showroom, where machines and methods can be arranged as closely as possible to conform with conditions existing in his own plant and is able to see the work carried out for him and is in many cases even able to time the processes. Since Philips are equally interested in all their sections and have represented them fully in their showroom, advice can be given without prejudice.

The importance of this service to Industry cannot be over emphasized. Constantly new needs demand new manufacturing methods or, with rising labour costs, old systems of processing work become uneconomical unless a better way can be found.

Philips would like to stress that their application showroom intends in no way to infringe on facilities already offered by various learned societies and official organizations, but aims to work in close co-operation with such bodies, extending their assistance to all irrespective of sales consideration.

Another Important Service of the Philips Application Showroom

Apart from helping those who are commencing new processes or improving their old ones, the showroom is able to render considerable service in the investigation of breakdowns, and other difficulties encountered in manufacture.

Weld cracking, filtration difficulties, testing or measuring metallurgical or chemical qualities, power factor and supply, weld timing or control and many other problems encountered in manufacture can be investigated and solved with the aid of the showroom, working in collaboration with Philips field engineers.

Another important section attached to the Philips Application Showroom is the Philips Arc Welding school where a capable instructor provides specialized and individual training for welders—whether they are apprentices or skilled welders wanting to learn new methods and welding processes such as the application of Contact Electrodes and Low Hydrogen Electrodes.

The Application Showroom Depends on its Users

Philips would like to point out that the showroom is very much a co-operative effort, and will not be successful unless the industry takes a direct interest in the utilization of the facilities offered.

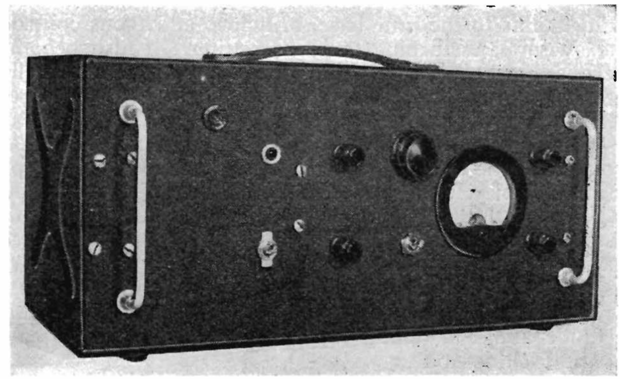
New Equipment Displayed at the Showroom

Included among the items of Philips' manufacture displayed are:

H.F. Dielectric Loss-Heating Equipment DF6/1.
High Frequency Induction Generator, type F18.
Ignition Contactor Units.
Double Gun Mobile Resistance Welding Unit.
Closed Circuit Television Equipment GM4900.

Measurement of Arc Voltage Drop in Mercury Rectifiers

By G. Ratcliff, B.Sc., Grad.I.E.E.
and R. G. Isaacs, M.Sc., M.I.E.E.

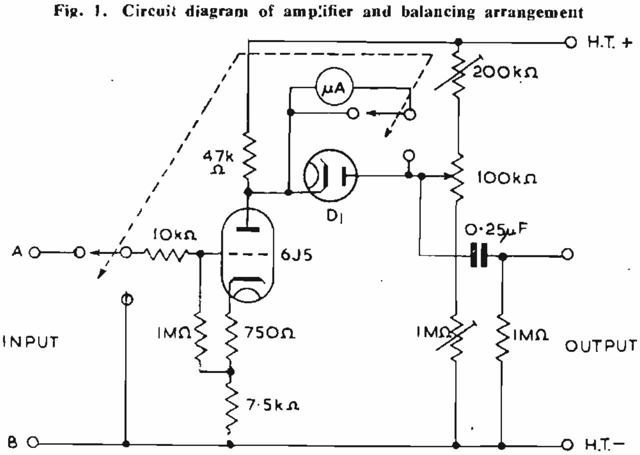


IN rectifier operation knowledge of the drop of volts from anode to cathode is important, for not only is this quantity responsible for the largest of the losses, but also its variation from instant to instant often provides the clue to any anomalous behaviour. Direct measurement of the arc volts is difficult; it has a value of about 17 to 30 volts, but at the end of each conducting period the anode-cathode space has to withstand an inverse voltage which will rise to a peak value of 20 or more times this amount and any measuring apparatus connected between anode and cathode will be subjected to this.

Wattmeter Methods

The usual method of measuring the arc loss and hence the mean voltage drop is the wattmeter method. In this the current coil of the wattmeter is connected between the transformer and the anode, the potential coil being between the anode and the cathode. The average value of the arc volts is then found from the wattmeter reading divided by the average value of the anode current, as read by a moving coil ammeter connected in series with the current coil of the wattmeter. There are two difficulties connected with this measurement. The potential coil resistance must be high enough to limit the current to a safe value during the reverse voltage periods. In the case of a six-phase rectifier this voltage will have a peak value equal to twice the peak value of the phase volts, and the high resistance required reduces the wattmeter reading (which is, of course, due to the current and the low arc volts during the conducting period) to a small fraction of the full scale reading. This reduces the accuracy of the measurement and rules the method out for low values of the current. Further, calculation of the correction required due to the loss in the wattmeter is complicated, whether the volt coil is on the anode side or the transformer side of the current coil, since neither the current nor the voltage is sinusoidal.

Fig. 1. Circuit diagram of amplifier and balancing arrangement



The wattmeter method can be considerably improved if the volt coil, with its series resistance set for a comparatively low voltage, is shunted by a diode which conducts when the anode to cathode volts become negative.[1] This parallel circuit is then put in series with a high dissipation resistance capable of carrying the current due to the inverse voltage. With this modification it is possible to increase the fraction of the full-scale wattmeter reading which is used. Further, if the diode has a resistance in the conducting direction which is low compared with the volt coil resistance, the correction for the loss in the coil becomes small and can be found with sufficient accuracy if a wattmeter reading is obtained with the rectifier under no-load conditions. If the quantity to be measured is the power loss in the arc this method is satisfactory for comparatively small rectifiers.

For rectifiers of large output, wattmeters of the required rating are unobtainable, and a current transformer of normal design cannot be used owing to the saturation of the core by the D.C. component of the current. This difficulty has been ingeniously overcome by Read,[1] using a shunt in series with the primary of the current transformer, the shunt being of the correct value for the injection of a D.C. component into the secondary circuit to neutralize the D.C. component in the primary. With this method, as with the previous methods, for low values of the current the voltmeter reading becomes too small for an accurate calculation of arc volts to be obtained.

It will be appreciated that with any wattmeter method all that can be obtained is the average arc voltage during the conducting period. If a knowledge of the striking volts or the variation of arc voltage during the conducting period is required, some other method must be sought.

Oscillographic Methods

A straightforward application of the anode-cathode volts to an oscillograph has been used as a method of arc volts measurement.[2] This has the advantage of showing the arc volts at every instant, but obviously a high degree of accuracy cannot be obtained since the low arc volts will only produce a displacement of the trace by a few millimetres, and in a cathode-ray oscillograph there is uncertainty about the position of the zero level, due to the self-centring action of the waveform when the deflecting plates are supplied with a highly unsymmetrical voltage. This method has been improved by applying the anode-cathode voltage to an amplifier with heavy negative feedback having a gain of about five for positive input volts.[3] A double-beam oscillograph is required, the output of the amplifier being fed to one pair of plates, the other beam being shorted to earth and used as a marker to indicate the zero level.

An extension of this circuit has been evolved by the authors, which dispenses with the need for a double-beam oscillograph and further, since the method to be described provides its own zero level indication, it is possible to make adjustments to the time base, brilliance and focus controls, etc., without disturbing the zero setting. It also becomes permissible to dispense with direct coupling to the oscillograph plates with the result that all the shift controls remain fully operative.

The circuit used is shown in Fig. 1. The anode-cathode voltage of the mercury arc rectifier is applied to the input terminals of a conventional amplifier employing a triode type 6J5. Heavy negative feedback is provided by the cathode lead resistors. The application of negative feedback provides a convenient control of gain and improves the response and stability of the arrangement.

The output is taken from the anode of the valve through a diode and a coupling capacitor to the deflecting plates of the oscillograph.

The anode of the diode is connected to a potential divider placed across the H.T. supply. In this way the diode behaves as an on-off switch, allowing the anode voltage variations to be passed on to the oscillograph only so long as the anode voltage lies below the potential to which the slider of the potentiometer is adjusted. At other times the diode is non-conducting and the oscillograph undeflected.

In order to set up the apparatus for measurement the input terminals of the amplifier are first short-circuited—a condition corresponding to zero input voltage. The potentiometer slider is now adjusted until there is zero difference of potential across the diode. This will be indicated by connecting across the diode a centre-zero micro-ammeter which may be made increasingly sensitive as balance is approached.

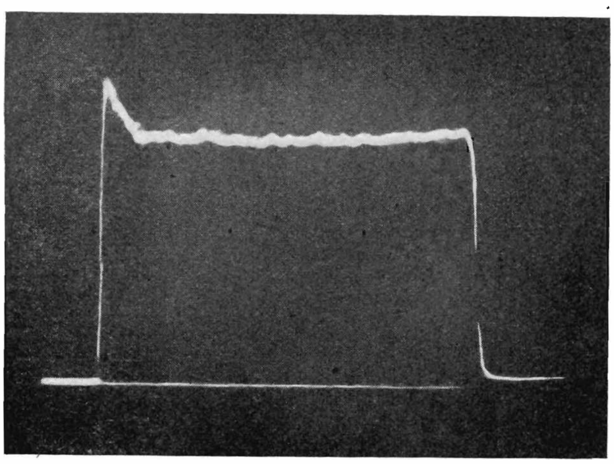
When the adjustment is complete, the short-circuit at the amplifier is removed and the anode-cathode voltage of the rectifier is applied to the amplifier so that the anode of the rectifier is connected to the grid of the amplifier.

If now the input voltage applied to the amplifier is at zero level the diode is on the point of non-conduction. On the rectifier anode becoming positive with respect to the cathode, a negative-going wave appears at the anode of the triode and is communicated through the diode to the oscillograph. For the period when the input voltage is reversed the diode becomes non-conducting and the waveform is not applied to the oscillograph.

The zero input level thus represents the demarcation between that which is applied to the oscillograph and that which is not. The waveform seen on the oscillograph is therefore an amplified picture of that part of the input voltage for which the anode of the rectifier is positive with respect to its cathode, i.e., that part for which an arc may exist.

A typical oscillogram for a mercury arc rectifier under load conditions is shown in Fig. 2. The arc voltage is represented by the height of the oscillograph deflexion above the base line. This height may, of course, be measured by applying a variable known sinusoidal voltage to the input of the amplifier and drawing a calibration curve of the whole apparatus.

Fig. 2. A typical oscillogram of arc voltage in a 10kW mercury pool rectifier under load conditions



A more convenient method is to add a variable D.C. bias to the voltage from the rectifier before connecting it to the amplifier as shown in Fig. 3. If the polarities are correctly chosen then increasing the D.C. bias voltage will cause a reduction in the height of the oscillogram. The D.C. voltage necessary to cause the flat top of the oscillogram to just disappear into the base line will be equal to the arc voltage.

It will be seen that the setting of the 100kΩ potentiometer slider is highly critical, since it is this setting which fixed the zero line of the oscillogram. Obviously no long-term stability can be expected from such an arrangement, and it is desirable that a push-button or two-way switch arrangement be provided which will simultaneously disconnect the rectifier, short-circuit the input terminals and connect the balance indicator across the diode. Thus frequent checks of the set zero may be made during measurements.

In practice it was found that, provided the amplifier was allowed a sufficient warming period, the zero set required adjustment only at very infrequent intervals.

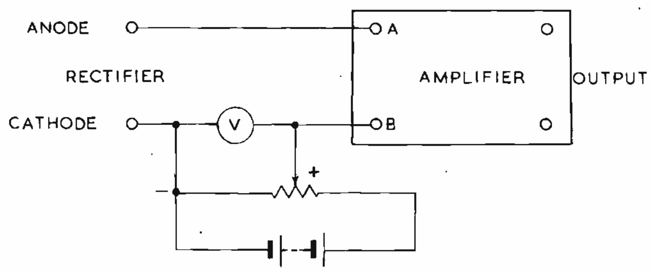


Fig. 3. Connexions for arc voltage measurement

The choice of valves to be used in this circuit will be a matter for consideration, having regard to the particular conditions in which the circuit is to be used. Thus the triode must be chosen so that the grid-cathode space will be capable of withstanding the inverse voltage of the mercury arc rectifier.

Reference to the circuit diagram will show that a series resistance has been included in the grid input lead as a safety measure.

The voltage which the diode must support may be readily calculated from a knowledge of the gain of the amplifier, the arc voltage and the cut-off voltage of the amplifying triode. If the gain of the amplifier is approximately five then the variations of voltage at the anode of the triode will be of the order of ±100 volts, and will be very little affected by the type of mercury arc rectifier to be tested. This is due to the way in which the triode fails to reproduce the inverse voltage swing beyond its cut-off point.

It is advisable to use separate heater windings for the triode and diode.

In addition to measurements on the mercury pool type rectifier, the method has been successfully applied to measurements of the voltage drops across hot-cathode rectifiers and thyratrons during conduction and to general investigations of their behaviour under various conditions.

REFERENCES

1 Read, J. C., "Efficiency Measurements on Rectifier Equipments." *The Engineer*, 171, pp. 142-144.

2 Higham and Wolfenden. "Voltage Regulation of the Six Phase Fork-connected Grid controlled Mercury Arc Rectifier." *Journal I.E.E. 83*, p. 174.

3 Benson, F. A. "Variation of Anode-Cathode Voltage Drop with Load Current in a Glass Bulb Mercury Arc Rectifier." *Beama Journal, 56*, No. 150.

Notes from the Industry

The Festival Convention of the British Institution of Radio Engineers will open on July 3 at University College, London, with a session on "Electronic Instrumentation in Nucleonics." A programme and a synopsis of seven papers to be presented at this session under the chairmanship of Dr. Dennis Taylor, M.Sc., Ph.D., of A.E.R.E. Harwell, are available from the General Secretary of the Brit. I.R.E.

Among the important subjects covered by these papers is the detection of radiation produced by atomic materials having both peace and war applications. In another paper the application to industry of a Beta-Ray thickness gauge capable of measuring and controlling a large number of manufactured materials is also discussed. In a third paper the important subject of radioactive tracers in industry and medicine will come under discussion.

Time will be given for ample discussion of each paper and full details will shortly be available of all the arrangements to be made for those who wish to attend this session.

Application to attend the first session should be sent to the General Secretary, British Institution of Radio Engineers, 9 Bedford Square, London, W.C.1, accompanied by a registration fee of 10s. 6d. The ticket for each session (registration fee 10s. 6d. in each case), will cover the cost of the Convention badge and literature, as well as afternoon refreshments.

The British Plastics Convention is to be held from June 6-16, in the National Hall, Olympia, London, W.14, in conjunction with the British Plastics Exhibition. It has been planned to appeal to technologists in the industry, users of plastics, and to the general public. For the plastics technologist, the Convention will take the form of a report on progress. A programme of papers and summaries, as well as tickets, may be obtained from "British Plastics," Dorset House, Stamford Street, London, S.E.1.

The Industrial Radiology Group of the Institute of Physics.—The Group's Summer Meeting will take place at the Institute's House, 47 Belgrave Square, London, S.W.1, from Monday, July 23 to Wednesday, July 25, i.e., in the week following the International Welding Congress. Further particulars may be obtained from the Honorary Secretary of the Group, Mr. B. N. Clack, Radiochemical Centre, Amersham, Bucks.

Patent Office Library—Extended Hours of Opening.—From May 7 the Patent Office Library at 25 Southampton Buildings, Chancery Lane, London, W.C.2, was open to the public from 10 a.m. until 9 p.m., Mondays to Fridays inclusive, instead of closing at 6 p.m. as previously. Saturday opening, however, continues to be from 10 a.m. to 5 p.m.

The Faraday Medal for 1951 (29th Award) was presented to Mr. Thomas Lydwell Eckersley, B.A., B.Sc., Ph.D., F.R.S., M.I.E.E., at a private ceremony held recently at the Chelmsford Works of Marconi's Wireless Telegraph Co., Ltd. The Medal was handed to Dr. Eckersley by Sir Archibald Gill, B.Sc.(Eng.), President of the Institution, who said that the Council of the Institution had awarded the Medal to Dr. Eckersley for his achievements in the field of radio research and, in particular, for his outstanding contributions to the theory and practice of radio-wave propagation.

The President was accompanied by Professor E. B. Moullin, M.A., Sc.D., and Sir Noel Ashbridge, B.Sc.(Eng.), Past-Presidents of the Institution and Mr. W. K. Brasher, M.A., Secretary of the Institution.

A New ASLIB Service.—In order to assist industrialists and scientific research workers to keep themselves informed of developments in research in foreign countries the Association of Special Libraries and Information Bureaux is preparing a central index of translations. The index will include scientific papers, reports and published articles which appear in foreign journals.

The usefulness of the index will depend on its comprehensiveness and to make this as wide as possible the co-operation of organizations at present in possession of translations is sought. All organizations holding translations and willing to take part in the scheme are invited to get in touch with ASLIB.

A limited number of translations has already been indexed and inquiries concerning the existence or location of translations are being dealt with. Inquiries can be made by telephone, letter or personal call. The name of the author or of the journal in which the paper sought for appeared should be quoted. There is no charge for the use of the index service.

All inquiries, and all offers of co-operation in the preparing of the index should be made to ASLIB, 4 Palace Gate, London, W.8 (Tel. WEStern 6321-3).

A Simple Frequency Comparison Circuit. We regret that an error occurred on page 197 of the May issue of ELECTRONIC ENGINEERING, under this heading. In the second paragraph in the centre column, the second sentence should read: "Thus if f_1 approaches f_2 the 'eye' will begin to flicker and zero beat can easily be observed when $f_1 = nf_2$ when n is an integer."

Dawe Strobotorch was described on page 187 of the May issue, but not the Frequency Meter and Photo-electric Pick-up, which is, however, included on page 238 of this issue. The Strobotorch's speed range is 120 to 14,000 r.p.m., not 14,400 as printed.

PUBLICATIONS RECEIVED

EDWARDS VACUUM GAUGES: THE "VACUSTAT." This four page leaflet describes what is claimed to be the "most popular gauge used today," and gives several new patterns, including a simplified version of the standard model. W. Edwards & Co. (London) Ltd., Worsley Bridge Road, Lower Sydenham, London, S.E.26.

EVERSHED INSTRUMENTS. For over 50 years Evershed & Vignoles Ltd., have been engaged in the manufacture of electrical instruments, naval control gear and apparatus for distant indication and control. This beautifully produced catalogue depicts their modern products including Megger insulation testers, bridge-Megger testers, ohmmeters, earth testers, recorders, tachometers, etc., and incorporates very brief descriptions. The illustrations are of a very high standard. Evershed & Vignoles Ltd., Acton Lane Works, Chiswick, London, W.4.

THE HYDRACLAMP is a brochure describing hydraulically operated work-holding equipment marketed by Spencer, Franklin Ltd., of 292 High Holborn, London, W.C.1. The brochure is well presented, and gives full details of many types of "Hydraclamp" available.

VALVE AND CIRCUIT NOISE. This booklet is the D.S.I.R.'s Special Report No. 20 and is a survey of existing knowledge and outstanding probems. This publication, in addition to dealing with valve noise and thermal noise in electronic circuits, covers noise in photo-electric cells, semi-conductors, crystal rectifiers, gas discharges and magnetic field devices. Available from His Majesty's Stationery Office, Kingsway, London, W.C.2, price 9d., by post 10d.

CONTINUOUS CONVEYOR FURNACES describes some of the many types of conveyor furnaces manufactured by Birlec Ltd., Tyburn Road, Erdington, Birmingham, 24. To meet the increasing demand for continuous and identical heat treatment of both ferrous and non-ferrous charges this firm specializes in developing this equipment. The brochure describes only the major types of conveyor furnaces and the illustrations represent a small percentage of the equipments installed.

ALKLUM is another well produced and illustrated brochure, this time on the Alklum nickel-cadmium alkaline batteries for marine service. The booklet fully describes the properties, performance and installation of these batteries. Copies are obtainable from Britannia Batteries Ltd., 66 Victoria Street, London, S.W.1.

LANCASHIRE DYNAMO HOLDINGS LTD. 1950 ANNUAL REPORT. This is an informative report about the various companies in the Lancashire Dynamo Holdings group, and includes some details of their individual activities. Obtainable from L.D. Group Publicity, 25 Shaftesbury Avenue, London, W.1.

G.E.C. QUARTZ CRYSTAL UNITS is a new edition of the list of these units, and in intended as a general guide to the range of quartz crystals available. They can now be supplied for any frequency in the range from 400 cycles per second to 16 megacycles per second for fundamental operation. Salford Electrical Instruments Ltd., Peel Works, Silk Street, Salford, 3.

ALUMINIUM ALLOY CASTINGS CONTAINING NICKEL is a booklet based on the paper presented by Frank Hudson, F.I.M., to the congress of The American Foundrymen's Society in May, 1950. It deals with all aspects of castings in these alloys, including early developments, recent metallurgical practice and modern production methods. It also contains a tabulated summary of the many alloys available. Copies may be obtained, free of charge, from the Mond Nickel Co. Ltd., Sunderland House, Curzon Street, London, W.1.

RADIO FOR MERCHANT SHIPS is a specification issued by the G.P.O. to cover the minimum performance of a combined radio-telegraph transmitter/receiver for use in lifeboats, and, as such, may be taken as forming the basis for type-approval tests. It may be obtained from His Majesty's Stationery Office, price 4d.

Letters to the Editor

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

Microwave Lenses

DEAR SIR,—Your very interesting series on "Microwave Lenses" by J. Brown and S. S. D. Jones was marred by the section "A Comparison of Lenses and Mirrors," in the October issue. At this time, some years after the introduction of metal plate lenses, it is quite generally recognized in this country that lenses are not the "cure all" for microwave antenna problems. I would like to indicate some of the reasons behind this attitude by considering the points raised in your publication.

If we pass over Kock's quite natural enthusiasm for lenses, we reach the argument that lenses are essential for very narrow beams. The authors gave as an example a 480 wavelength lens constructed in this country. I personally do not believe that such a lens exists. Perhaps the 480 wavelength reflector here at the Naval Research Laboratory is the antenna to which the authors refer. This mirror was found to be well within the 1/32in. tolerance permitted at X-band. The differential heating has been considered and it is felt that with uniform distribution of heat over the surface, no great errors will be introduced. A lens with its correspondingly longer local length is entirely impractical for this project.

For Naval radar application, it appears that a lens will in general weigh at least twice as much as the comparable reflector, not counting the extra weight required to support the feed structure at a greater distance from the reflector. (See N.R.L. Report 3412).

I will freely admit that a lens indicates better scanning properties for a wide angle of scan. However, notwithstanding the work done on lenses by Dr. Spencer's group in this country, the problem of wide angle scanning has not been solved by lenses, and there is considerable doubt whether it ever will be solved in this manner.

The arguments on the basis of feed obstruction have worn thin with the years. One fundamental point is missed entirely by the lens adherents. The increase in side lobe level and decrease in gain are directly related to the ratio between the area of the reflector obstructed by the feed to the total area of the reflector. For an ordinary mirror with a beam width of 2° at half power point the ratio is about .002 which introduces a gain loss of less than .01db. Since the side lobe level at 30db would only be increased by 0.6db, there appears to be little trouble with obstruction of a mirror. These figures are based on the standard discussion of feed obstruction such as given in Cutler's article in the November, 1947, I.R.E. Proceedings. This general information has been verified experimentally in the work abstracted by Adams and Kelleher in the September, 1950 I.R.E. Proceedings.

In regard to the point of using an offset feed, I can think of no reason why the gain should be reduced. It is fundamental that the gain of reflector, half reflector or lens depends only on the illumination over the aperture of the system. Therefore, for a fixed illumination the only loss in gain is due to spillover or in the case of the lens due to reflexions and to the difficulty of obtaining the desired aperture illumination.

Neither the lens nor the mirror can be considered superior as regards side lobe level, since side lobes depend only on the distribution of energy over an aperture. Some information on this appeared in the Marconi Review of October-December, 1947. The work of Adams and Kelleher covered both analytical and experimental results using a mirror. No difficulty was experienced in obtaining verification of the side lobe level predicted by the theory. The lenses built to date appear to have poor phase characteristics particularly when stepped lenses are employed, and so higher lobes might be expected in this case.

The mismatch of the feed due to the reflector is always negligible for any system of reasonable f/λ ratio. I do not know of any recent programme using reflectors which attempts to compensate for this mismatch by use of a zone plate or otherwise. Measured and calculated values of this reflexion coefficient for a typical antenna are given in N.R.L. Report 3412.

The back-to-front ratio of the shielded lens is superior to that of a reflector. However, this advantage applies only to repeater links, in which the crosstalk problem makes the extra lens expense feasible. In discussing repeater links, it is well to note that at the recent Scanning Antenna Symposium at N.R.L. a Bell Telephone Laboratory representative stated that the lens corrected horns, or shielded lenses, possessed the same 3db loss typical of the ordinary metal plate lenses.

In conclusion, it is agreed that the lens may have wide angle properties and when used with a shield does have low back radiation. However, for gain, side lobe suppression, and simplicity, the reflector has proven superior.

Yours faithfully,

KENNETH S. KELLEHER,
Naval Research Laboratory,
Washington D.C., U.S.A.

The authors' reply:

DEAR SIR,—Mr. Kelleher has raised a number of interesting points and has provided additional information which was not available when we prepared our articles. This does not, however, affect our main conclusions which are in most respects the same as Mr. Kelleher's. We have never believed that lenses are the answer to every aerial problem and it was made clear in the section to which Mr. Kelleher takes exception that reflectors are to be preferred when gain is the primary consideration.

The major point on which we disagree with Mr. Kelleher is side lobe suppression. There is no question that the side lobe level depends on the aperture distribution and our contention is that it is easier to obtain the distributions required if a lens is used. The amplitude distribution over the aperture of a reflector is determined by the radiation characteristics of the primary feed and the control of the distribution is relatively crude. In a lens, on the other hand, a further control of the distribution results from the possibility of curving both surfaces. One relation between the two surfaces is sufficient to satisfy the phase requirement and the other may be used to control the amplitude distribution. A much finer variation of amplitude distribution is therefore possible. Much work remains to be done on this problem and this was one of the points we had in mind when we predicted further advances in lens techniques.

On the much vexed question of feed obscuration, the first point we should like to make is that the effect becomes less marked the larger the aerial aperture. By considering a relatively large aerial, Mr. Kelleher has shown that the effect may be slight. On the other hand, there are many applications in which the effect is far from slight. A most important practical case has been considered in detail by Kiely, Collins and Evans,[1] viz., the cheese aerial used in the majority of marine navigational radars. They have found an increase in the level of the first side lobe equal to over 2 per cent of the amplitude of the main beam from feed obscuration. In addition, they have shown that the dimensions of the feed in the direction of propagation also has an effect—by no means negligible—on the side lobe level. As a result of these effects Kiely et al. claim that the side lobe level of a normal cheese cannot be better than 25db down on the main beam. Lack of space prevented us from giving a full discussion of feed obscuration in our articles, but we trust that it is clear that it is still a practical problem to be considered in the design of reflectors.

We would like to reply briefly to the other points raised by Mr. Kelleher. The 480 wavelength lens to which we referred is described by Kock in his original paper on metal-plate lenses.[2] The aperture is only 480 wavelengths in one direction: Kock claims that the performance is in good agreement with theoretical predictions. We think that the construction of large aerial systems is made simpler by the use of lenses, and that it will be possible with the development of manufacturing techniques to keep the weight about equal to that of a reflector of corresponding aperture dimensions.

If a reflector is fed by an off-set feed the amplitude distribution will be assymetric and there will be a loss of gain. It is possible to correct some of this assymetry by a suitable choice of feed, but this choice is restricted by the necessity of keeping the side lobes resulting from spill-over below the required level. This point is also discussed in Reference 1.

We wish we could agree with Mr. Kelleher that zone plates are no longer in use. We have had occasion recently to match a cheese over a large range of wavelengths and the use of a zone plant was found to be essential. The deterioration in side lobe performance was considerable.

The side lobes produced as the result of phase distortion in the vicinity of steps will be far removed from the main beam and will usually be of smaller amplitude than the first side lobe. A particularly severe case, in which these far-out side lobes do exceed the first, is shown by Ruze:[3] the number of steps in the lens involved is not stated, but must have been around nine. With a smaller number of steps the effect is much less severe.

Lens corrected horns are free from spill-over loss and the reflected energy will not be scattered in the form of diffuse backward radiation but will be concentrated back into the waveguide feed. An iris placed at the horn throat will cause this reflected energy to be again propagated through the horn, and hence it will be focused by the lens. It would therefore appear that the gain of a lens corrected horn should exceed that of the corresponding unshielded lens by the amount of the spill-over and reflexion losses. Our own measurement of the gain of a lens corrected horn gave a value of about 80 per cent for the efficiency. The lens involved had only one step and an increase in the number of steps would reduce the efficiency: it is therefore worth making the lens in a horn thicker than necessary in order to reduce the number of steps.

The authors are indebted to the Chief Scientist, Ministry of Supply and the Controller of H.M. Stationery Office for permission to publish this reply.

Yours faithfully,

J. Brown and S. S. D. Jones,
Radar Research and
Development Establishment.

REFERENCES

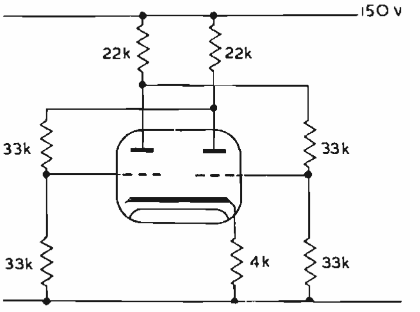
1. Kiely, Collins and Evans: "Cheese Aerials for Marine Navigational Radar." Proc.I.E.E., Vol. 98, Pt. III, p. 37, 1951.
2. Kock, W. E.: "Metal-Lens Antennas." Proc.I.R.E., Vol. 34, p. 828, 1946.
3. Ruze, J.: "Wide-Angle Metal-Plate Optics." Proc.I.R.E., Vol. 38, p. 53, 1950.

A Three State Flip-Flop

Dear Sir,—I was very interested to read the note in the April 1951 issue of Electronic Engineering on a flip-flop circuit showing three stable states. So far as I know this effect is novel and it should certainly prove useful in many applications, such as in computing machines and as a scale of three counter.

The explanation of the phenomenon puzzles me, though. Surely all Nyquist's criterion can show, under the conditions mentioned, is that the symmetrical condition is metastable? In practice, of course, there is always some reactive effect present and surely a state "meta stable at a first approximation" would in fact be unstable?

Is is not true that the real explanation lies in the fact of grid current? The authors quote the grids as being 0.15V below the cathode potential, and it is surely well known that in a valve with a cathode at 7-800°C the peak emission energy is of the order of one volt or even more, so that electrons can easily reach a grid at −0.15V. When grid current is flowing, of course, the loop-gain of the circuit is vastly reduced due to the low input resistance of the grid replacing the lower half of the resistance network from the anode.



Modified Three State Flip-Flop

This theory is confirmed in theory with the use of the published curves for the 6J6 in the R.C.A. Handbook. For if the voltages in the symmetrical steady state are considered in the absence of grid current we find, from the curves, that (assuming for the moment $V_g = 0$) the valve drops 32.5V when passing 3.25mA. In this case the cathode resistance (4k at 2 × 3.25mA) has 26 volts across it, and the anode voltage of 58.5 agrees well with your value of 56V. Moreover, the current in the anode load agrees, in the case I have taken, with an H.T. line at 154 volts, so that the anode voltage agreement is even better than it seems at first.

The whole point of this complicated calculation is to show that *in the absence of grid current* theory predicts a grid voltage of (58.5/2 =)29.25 above earth, or 3.25 volts above the cathode. Hence it seems reasonable that grid current does, in fact, flow and that the grids are pulled down to the voltage you have measured in experiment.

Moreover, the amplification of each valve under these conditions cannot be greater than 20, whereas the grid input resistance with a 6J6 should certainly be less than 1.5k, so that with 33k resistances between anodes and grids the net loop-gain is *less than unity* and consequently the system is entirely stable. You will notice some approximations in this argument, but I think it is true to say that more careful consideration will only strengthen the final conclusion.

The problem now seems to be to explain the original two stable states, for if both valves are "bottomed" it seems that it will be impossible to drive one harder so that the other can be cut off But this is not so; as soon as either of the grids goes far enough negative to stop taking current the loop gain rises sharply to a value greater than unity, and that valve is driven to cut off. The common cathode resistance, to my surprise, appears to have no part in the action and is quite unnecessary except as a means of adjusting the cathode voltage to a critical range.

According to my calculations the grid current in the conducting valve rises from 0.2mA in the symmetrical state to nearly 2mA in the asymmetrical state. This causes the anode-cathode voltage in that valve to fall from over 30 volts down to 10, with scarcely any change in the total cathode current, and consequently the grid voltage in the other valve is driven down to cut off quite easily.

The effect of adding cross-coupling capacitances to such a system is to increase the loop gain at high frequencies. Presumably with the circuit constants concerned, one such coupling was insufficient to raise the loop gain above unity in the symmetrical state (remember the Miller capacitance at the other grid). With two capacitances, however, presumably the gain was raised far enough for instability, even in the symmetrical position, so that the circuit showed only the usual pair of stable positions.

It is not easy, though, to see why the single capacitance circuit should make a reliable scale-of-three counter and I am certainly interested to hear that it does. It seems fortuitous that the voltage established across the capacitor in each state should be just right for it to move to the next on triggering, in a cyclic progression.

I hope that this letter may be of some help in clearing up the theory of this interesting device, and I hope that you will be encouraged to publish any further developments of the circuit.

Yours faithfully,

K. C. Johnson,
Radio Group, Cavendish
Laboratory. Cambridge.

Dr. Booth and Mr. Ringrose reply:

Dear Sir,—We have no disagreement with the explanation of the action of the three stable state flip-flop put forward in the letter of Mr. Johnson.

We are afraid that the original explanation given in our article was perhaps misleading since we in fact meant that the loop gain of the system is less than unity. The absence of reactive elements in the circuit, at any rate to a first approximation, is, however, necessary to avoid the violation of this condition at high frequencies.

Since the original note was written we have made measurements of loop gain which confirm not only that this is less than unity, as suggested by Mr. Johnson, but also that grid conduction occurs in both valves.

Yours faithfully.

A. D. Booth and J. Ringrose,
Birkbeck College Research
Laboratory, London. W.C.1.

High-Speed Waveform Monitor

Dear Sir,—On page 60 of the February issue of Electronic Engineering we were interested to note a reference to the E.M.I. Waveform Monitor Type 3794B.

There was, however, an error in the first sentence in that it attributed the design and development of this equipment to A.E.R.E. Harwell.

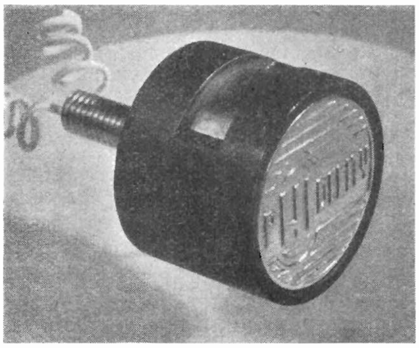
In point of fact E.M.I. Research Laboratories, Ltd., were solely responsible for the design and development of this Monitor which is now manufactured and marketed by E.M.I. Factories, Ltd.

Yours faithfully,

P. O. Wymer,
Press Relations Officer.
E.M.I. Sales & Service, Ltd.

ELECTRONIC EQUIPMENT

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



Magnetic Tape Recording Head
(Illustrated above)

MESSRS. Phidelity Magnetic Products, Ltd., have started production on a range of magnetic tape recording heads which are suitable for a requirement of the recorder manufacturer and the home constructor.

The heads are made up of laminations of magnetic steel, worked to close precision limits. The gap depth is held to the minimum figure possible, and the windings are specially designed for maximum flux density at the smallest audio currents. All heads are mounted in non-magnetic holders designed for single screw fixing, and are available in the following types: Type SA which is a dual purpose record and playback head with a gap of .001 inch; Type SE is a supersonic erase head suitable for low coercivity tape, with a gap of .0005 inch; Type SR is a recording head with separate audio and bias windings, with a gap of .001 inch. and Type SP is a very high fidelity playback head, with a gap of .00025 inch. All four types have low impedance winding. All heads are for full ¼ inch track, but half track heads to the same specification can be supplied.

Phidelity Magnetic Products, Ltd.,
65-66 Chancery Lane,
London, W.C.2.

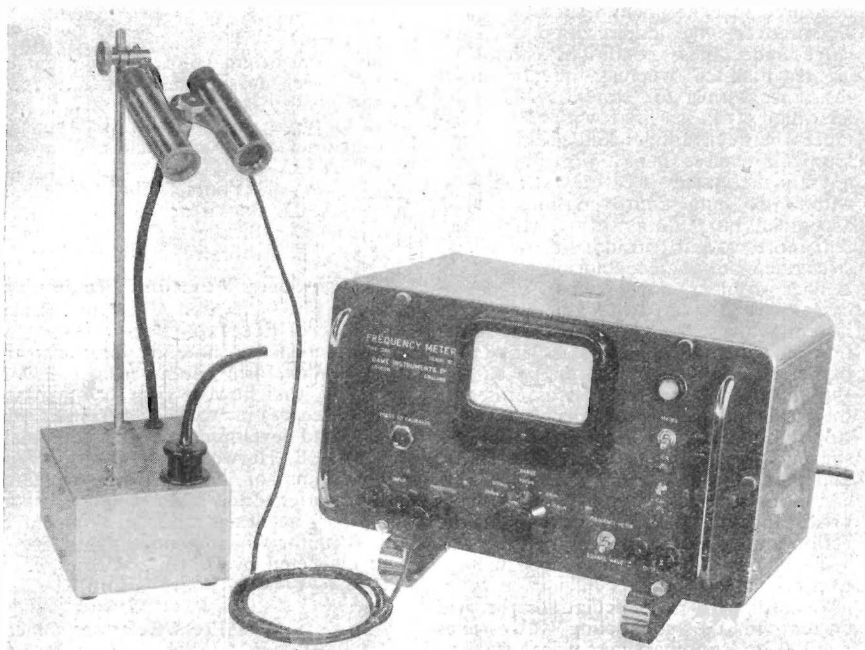
Dawe's New Frequency Meter
(Illustrated below left)

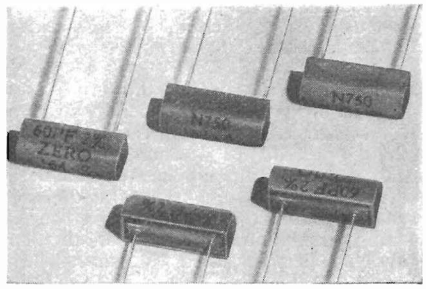
The Frequency Meter and Photo-Electric Pick-up Type 714 are designed to provide a means of measuring rotational speeds without imposing any load on the machine being tested. The meter has a range of 5c/s to 15,000c/s.

Features are: wide speed range—up to 900,000 R.P.M., which is well beyond the rotational velocities of practical machines; no load is imposed on machines being tested; it is suitable for measurement of varying speeds such as are encountered on small centrifugal gyroscopes and rotors; readings are reliable within ± 1 per cent; it incorporates a direct reading frequency meter, and an A.C. mains frequency check is included.

The apparatus consists of a lamp which is focused on the rotating mechanism marked with contrasting sections and a photo cell whose current is modulated by the reflexions from these sectors. The modulation output, after passing through a pre-amplifier in the pick-up unit, is fed to a frequency meter. By using a suitable number of sectors, speeds from below 100 R.P.M. to 900,000 R.P.M. can be measured.

Dawe Instruments, Ltd.,
130 Uxbridge Road,
Hanwell, London, W.7.



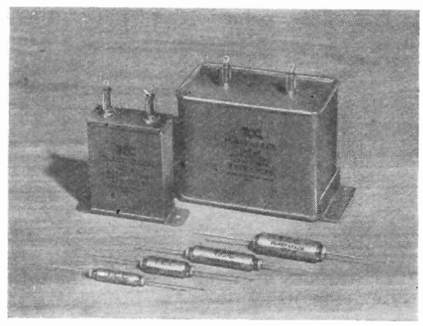


New T.C.C. Capacitors

ILLUSTRATED above is the "Plimoseal" protected ceramic and mica capacitors. Each capacitor is mounted in a moulded casing which is then filled with a specially developed plastic immersion sealing called "Plimoseal." This method, claim the makers, enables the 100 per cent humidity 100°C requirements of Category A Ministry specifications to be met.

Illustrated below is the "Platapack" plastic film dielectric capacitors, for use in counting circuits and allied computing devices, and under other stringent conditions, which have had their working voltage stepped up to 350V D.C. The tubular construction now employs an outer tube of silvered copper sealed by P.T.F.E. bungs. The range has been extended, both in the rectangular metal and tubular constructions.

Telegraph Condenser Co., Ltd.,
Wales Farm Road,
North Acton,
London, W.3.



Model 69 High-Gain Stacked Television Aerial

THIS development by Aerialite, Ltd., actually consists of two Model 64 television aerials each having a power gain of 10.6 dbs., the total output being approximately 20 times that of a plain half-wave dipole, and eight times that of an "H" aerial. The aerial is normally supplied with a 16 foot mast having chimney brackets, but the aerial may be fixed to a wall or guyed mast as desired.

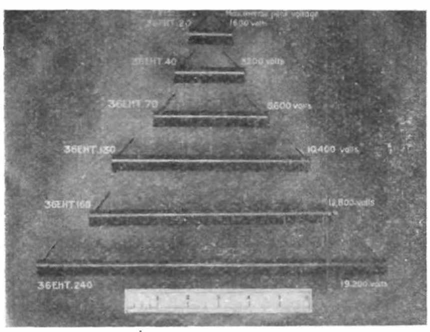
The special features of this aerial are: unidirectional pick-up since the acceptance angle is only 68°, reducing interference from all other directions with a high front/back ratio; high forward gain of approximately 13 decibels; wide bandwidth due to large diameter folded dipole and wide spacing of elements; good vertical pattern giving good discrimination against ignition interference; matches 70 Ω downlead by two "Q" sections transforming the impedance to give correct operation; rugged construction is achieved by using steel booms and mast, with large folded dipole and strong castings where possible; erection is made easy by using U-bolts throughout which allow quicker adjustment, and the cables are fixed by detachable plug assemblies.

The model 69 is a stacked array consisting of twin 4-element Yagi aerials each having parasitic reflectors and two directors widely spaced to give high gain, without heavily loading the dipole or reducing the bandwidth.

The actual impedance at the dipoles on each side would be in the region of 13 ohms, were a plain dipole to be used. However, this is transformed by the folded dipole of unequal diameters to 70 ohms and by the 100 ohm "Q" section to 140 ohms. The two "Q" sections in parallel then give a 70 ohm feed point for the downlead.

Either twin or co-axial feeder may be employed, and any unbalance is reduced by the ¼-wave balancing-lines acting as "Q" sections.

Aerialite, Ltd.,
Castle Works,
Stalybridge,
Cheshire.

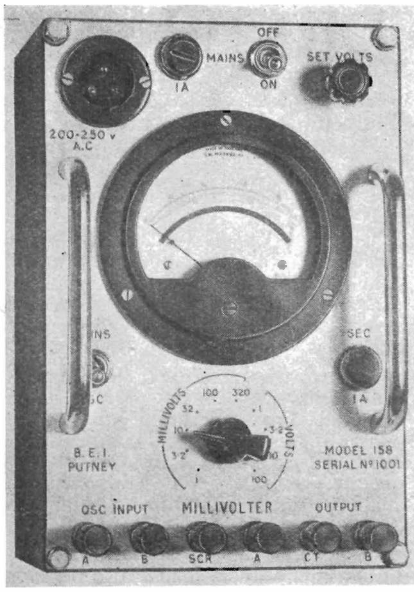


36 E.H.T. Range of "Westalite" Tubular Rectifiers

ILLUSTRATED above is a range of 36 E.H.T. "Westalite" tubular rectifiers by the Westinghouse Brake & Signal Co., Ltd. This range has been manufactured for providing E.H.T. when the current demand is unlikely to exceed about 2mA D.C., and incorporates the recently developed high-voltage "Westalite" elements, and to withstand peak inverse voltages of about 1200-1300 per inch length of rectifier.

These units are particularly suitable for voltage multiplier circuits such as voltage doublers, triplers, etc., owing to their small size and low forward resistance, and they will operate effectively as pulse rectifiers to derive E.H.T. from the flyback pulse, which occurs at the line scanning output transformer of a television receiver.

Westinghouse Brake & Signal Co., Ltd.,
82 York Way,
King's Cross, London, N.1.



Peak to Peak Millivolter L.S.158

(Illustrated above)

THE British Electronic Industries Millivolter L.S.158 gives the following facilities: a reasonably low voltage output on the lowest scale; one per cent accuracy of output; low source impedance so that circuits normally met will not cause a shunt loss of more than one per cent; a sufficiently high voltage for direct calibration of cathode ray oscilloscope tubes; balanced and unbalanced outputs; A.C. mains or oscillator tone input, and readings made by circuits responding to peak to peak voltage instead of R.M.S. volts.

Ranges are in ten steps from 1mV with a source impedance of 1.2-0-1.2 ohms to 100V with a source impedance of 500-0-500 ohms.

British Electronic Industries,
28 Upper Richmond Road,
Putney, London, S.W.15.

Voltage Reference Tube on Miniature B76 Base

IN order to meet the demand for an extremely compact and stable source of voltage reference for direct use in electronic circuits, Mullard Electronic Products Ltd. have recently introduced a miniature Voltage Reference Tube, 85A2. This new tube, which is of robust construction, is built up on a B7G base, and should prove of particular value in the design of scientific and industrial electronic instruments in which the demand is for extremely accurate and reliable performance, combined with the maximum conservation of space.

Working in a constant current circuit, the 85A2 provides a voltage source having a short-term stability of better than 0.1 per cent and a long-term stability of better than 0.2 per cent. It also has the advantage that this high stability is maintained even under intermittent switching conditions.

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

Kabi-Austinlite D.P. Rotary Switch

(Illustrated below)

DEVELOPED for meter switching duty, the Kabi-Austinlite D.P. Rotary Switch was designed to overcome inconsistant contact resistance, inaccessibility and double tier terminations.

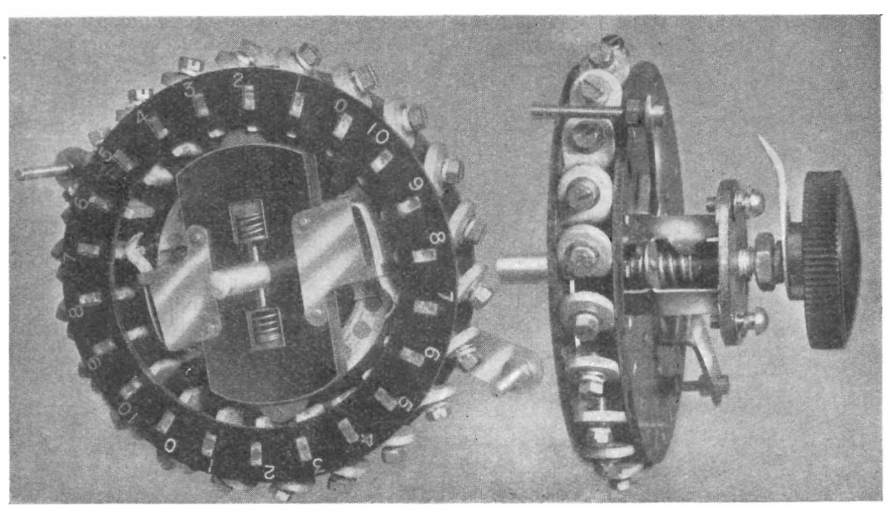
The chief cause of variation in contract resistance is the presence of dirt on fixed contacts, but raised air-spaced contacts prevent this. The construction is such as to make dismantling easy, and give an unimpaired view of the switch action and contact condition. All terminals are arranged in a single plane near the panel. Slotted hexagon-headed screws are used.

The switch can be employed as a tapping switch on a non-inductive circuit, or can be arranged as a 10-way and off double pole, or else as a 20-way single pole with two off positions. The maximum rating is 5 amps. 230 volts D.C.

The switch has a slow make and break action. Balanced loading is achieved by two spring-loaded plastic plungers arranged diametrically opposite.

The standard switch is arranged for alternative mounting on ⅛ in. metal or up to 1 in. thick insulation without modification.

Precision Components (Barnet), Ltd.,
13 Byng Road,
Barnet, Herts.



BOOK REVIEWS

Encyclopaedia on Cathode Ray Oscilloscopes and Their Uses

By J. F. Rider and S. D. Uslan. 992 pp. 3,000 figs. approx. John F. Rider Publisher Inc., 1950. Price $9.

THE task of giving a fair, objective review in a few paragraphs of a book containing a thousand large pages and probably a million words, together with several thousand diagrams and photographs, is obviously virtually impossible.

This work is a remarkable production even if its size were its only merit, and one can only marvel at the immense labour represented by its compilation. It is indeed an encyclopædia in all senses of the word. There are twenty-two chapters, three appendices, a comprehensive bibliography, and an index.

In general the work is addressed to technicians rather than to professional engineers. The style is straightforward and factual, but one feels that the work could have been greatly condensed without loss of clarity. This is especially true of the early chapters and applies, with particular force, to Chapter 8 on "Spot Displacement." Surely it would be possible to condense this into not more than a page. The reviewer finds it rather difficult to visualize the type of person who would wish to buy a book containing so much detail and who would yet find need of the lengthy and rather elementary descriptions which abound. There is also much repetition.

It is a pity that it has this defect, for there is imbedded in it the whole science of oscillography, and the work is a mine of information. Certainly there is no other publication containing, in one volume, so much on this subject.

There are a few statements which would worry a specialist and would mislead the beginner. There is a misleading idea on page 42, for example, dealing with the effect of baffles on cross-over size. Figure 2.23 shows a long delay period before the electron beam is deflected. There are peculiar statements on page 111—for instance, "It has been found that the position of the focus coil tends to affect the spot dimension." Is the reader supposed to be surprised by this obvious fact? This section entirely fails to differentiate between the effect of basic spot size change as a result of changing the image/object ratio and the disturbing influence (quite irrelevant in a scientific sense) of spot size change due to abberation caused by variation of beam width in the focusing coil.

In about twelve hours conscientious reading the reviewer has detected about twenty such instances, but to see the matter in proper perspective one must note that the book contains about fifty thousand sentences and that on the whole the standard of accuracy and freedom from typographical error is very high indeed. The work is illustrated generously with illustrative photographs of cathode-ray tube traces and there is a particularly useful section classifying a large variety of complex wave shapes.

In brief, this is an immensely comprehensive work which will appeal to the technician. The engineer will be somewhat irritated by the very lengthy style and by a general failure to link the factual statements with basic physics.

HILARY MOSS

Acoustic Measurements

By Leo L. Beranek. Pp. 914 and 550 illustrations. John Wiley and Sons, Inc. and Chapman and Hall, Ltd. 1949. Price 56s.

THIS book brings to the research engineer and the student the experience of many years in the practical field of acoustic measurement. Since the measurements themselves are sufficiently complex as to necessitate a knowledge not only of the apparatus employed, but also of the fundamental factors involved, the author is at pains to present the mathematical equations first, before describing the method of measurement. He states clearly what are the essential features of a particular investigation and compares the advantages and disadvantages of the many techniques.

The early chapters are concerned with the basic properties of the more common mediums in which sound is transmitted and conclude by discussing the propagation of sound waves of large amplitude in ideal gases. Next the effect of obstacles on the free field sound pressures are examined and the information presented, not only mathematically but also in the form of graphs and curves. Most of the recognized methods for the calibration of microphones are described, but the author concentrates rightly on the Rayleigh disk and reciprocity techniques. This chapter and that portion of the book devoted to the measurement of acoustic impedance are outstanding not only for their treatment, but also for the practical information collected from many sources and made available for the first time in one volume. There are also some very interesting sections on the characteristics of random noise, the testing of loudspeakers, communication systems, and studio microphones.

While the capacitor and piezoelectric microphones receive adequate treatment, scant attention is paid to the electrodynamic types, especially to the ribbon. It is difficult to see why use is not made of the graphs of pressure and phase change around obstacles (already available in Chapter 3) to discuss the behaviour of the ribbon microphone in both plane and spherical sound fields.

One cannot do justice in an all too brief review to a work of this size, but there is no doubt that Dr. Beranek's admirable book is a worthwhile contribution to the all too scanty literature on the subject of acoustic measurement. It can be recommended with every confidence to the research physicist or the psychologist interested in the mechanism of human hearings, as well as to the audio frequency engineer.

A. E. ROBERTSON

Theory and Design of Electron Beams and Travelling-wave Tubes

By J. R. Pierce. 197 and 260 pp. MacMillan & Co. Ltd., London. 1949 and 1950. Price 26s. and 34s. respectively.

THESE two volumes in the Bell Telephone Laboratories Series of technical publications are to some extent complementary. The first deals with the methods of producing and controlling electron beams, and their behaviour in steady or slowly varying fields. The second is concerned with the interactions of electron beams and high frequency electric fields. Both books deal with subject-matter which has been applied with remarkable success, during the last decade or so, in the field of ultra-high frequency amplifiers and oscillators. The author, as one of the chief contributors to this success, is extremely well qualified to write on these subjects, and he has produced two volumes which will be of great value to anyone engaged in the design of electron beams, or ultra-high frequency valves.

The advent of klystrons and travelling-wave tubes has forced the study of electron optics upon the high frequency valve designer. The problems are similar to those in other fields, but the outlook is rather different. It is in this respect that Dr. Pierce's book on electron beams differs from other standard texts on electron optics. The first four chapters deal with the theory of electron motion in electric and magnetic fields. In chapter 5, empirical methods, such as rubber models and electrolytic tanks, are considered in connexion with some special practical problems in valve design, e.g., electron multipliers, frequency changers and reflex oscillators. The next two chapters deal with the theory and practice of electron lenses. These are followed by two chapters on the limitations imposed by thermal velocities and space charge on the current density of beams. Finally there is a chapter on electron guns.

The volume on travelling-wave tubes covers, in some detail, most of the known aspects of the small signal theory of these devices. An introductory chapter discusses the unique properties of the T.W.T. with regard to band width and frequency range. The general relations for the propagation of waves in the circuit-beam system are then established, and it is shown theoretically that, under certain conditions, a wave of increasing amplitude may be set up when the wave velocity in the circuit is approximately equal to the electron velocity. Helices, loaded wave-guides and series resonators are all considered and compared as circuits for propagating slow waves. There follows further treatment of the circuit-beam relationships and the conditions for high gain. Circuit losses, discontinuities, space charge effects and random noise are all analysed with reference to the small signal theory. One chapter is devoted to a qualitative discussion of large amplitudes and power output. The book concludes with two brief chapters on magnetron amplifiers and the intriguing double stream amplifier. There is no consideration of the closely related subject of the linear accelerator.

In both books the author claims to have dealt mainly with those parts of his subjects which are amenable to analytical treatment. To some extent he does himself an injustice. Both books are full of numerous intimate practical details which arise spontaneously from the author's deep fund of experience. Some readers may consider these practical titbits of greater value than much of the mathematical analysis, with all its inherent limitations. Intending readers are recommended to begin with the brief concluding chapter of the first volume. There, the author puts the mathematical treatment of electronic devices in its proper perspective.

These two authoritative books can be thoroughly recommended to anyone engaged in the fields of electron optics or ultra-high frequency electronics.

M. R. GAVIN

Principles and Practice of Radar

By H. E. Penrose and R. S. H. Boulding. 708 pp. 550 diagrams. 3rd Edition. George Newnes Ltd. 1950. Price 42s.

THE appearance of a third edition of this book so soon after the second is a sign of the rapidity of the development in the field of radar. In order to make the third edition as up-to-date as possible the authors have fully considered microwaves and the particular problems met with at these wavelengths. Some new developments, such as lenses and slot aerials, have also been included.

A new chapter, dealing with examples of marine radar installations are interesting reading, and includes an illustrated description of the harbour installation at Liverpool.

Radio Laboratory Handbook

By M. G. Scroggie. 430 pp. 169 diagrams. 5th Edition. Iliffe and Sons Ltd., 1950. Price 15s.

THE principles of radio and electrical measurements are fundamentally the same whether the apparatus used is professionally made or is merely an amateur's temporary "hook-up." In this handbook the author describes the methods available for carrying out tests and measurements, using either commercial instruments or improvised equipment.

His subjects include the principle sources of power and signals, the various types of measuring and acoustic instruments, methods of comparison and their application to receivers and amplifiers, and the plotting and interpretation of results.

There is also a special chapter on laboratory technique for V.H.F. work, constructional details of capacitance and resistance and inductance bridges, and much useful general information on such varied subjects as musical scales, decibels, wire gauges, filters, building one's own gear, etc.

The fifth edition has been revised and new material added—in particular, the more recent developments in valve oscillator design.

Photons and Electrons

By K. H. Spring. 100 pp. 38 Figs. Methuen's Monographs on Physical Subjects. 1950. Price 7s. 6d.

MANY electronic engineers must look back with a certain regret to the days when particles were particles and waves were waves. The impossible task of explaining wave mechanics in 100

BOOK REVIEWS (Continued)

pages has not been attempted by Mr. Spring in his little book, but he has made a most useful collection of the theoretical formulæ with clear and concise explanations of their physical meaning, and descriptions of the supporting experimental evidence. There are many ways in which electrons and photons can interact and all ways now known are described and clearly distinguished. A particularly good discussion of the different types of γ-ray absorption is given.

Many of the formulæ given are complex, and when the book is used for reference, a list of symbols at the end would be useful, although great care has been taken to define at some point in the text all the symbols used. Some of the formulæ will prove irritating to the practical man who wishes to substitute figures in them, as, after a series of numerically known quantities one comes for example upon an inconspicuous little "$f(T_{01}T)$" where "$f(T_{01}T)$ is a function of the variable given by Heitler," but references are always given from which such problems can be resolved.

In one or two places hurried reading might leave a misleading impression, as where it is stated that "many true pairs (of electrons) are found with different energies" (from those theoretically predicted).

An outline of the Dirac theory of the positron as a "hole" in a sea of negative-energy negative electrons is given clearly and concisely, though without throwing more light than usual on such points as the presumed density of such a sea or on the effects of the space-charge resulting.

For a book published in 1950 the data on mesons is rather out-of-date, but these lie outside the book's main field and in spite of such minor points, this is a very useful little book, giving a summary of information obtainable otherwise only with considerable effort.

J. H. Fremlin

Ultrasonics

By P. Vigoureux. 163 pp. 74 Figs. 1st Edition. Chapman & Hall Ltd. 1950. Price 25s.

THE number of scientific textbooks on the subject of ultrasonics can be numbered at present on two hands. It is therefore very gratifying to see that the latest work on this subject is of British origin and is actually the first to be written by a British author. In the past, American, German and French authors have monopolized this field of publication, and although many fundamental papers have appeared in this country, Dr. Vigoureux is the first to concentrate on the production of a complete textbook.

The book covers the generation and theory of propagation of ultrasonics and the clearness of presentation should be an example to the writers of standard textbooks in other fields. There are three main chapters covering generation, propagation and observation, together with two further chapters on the phenomena encountered when an ultrasonic wave is propagated through liquids and gases.

The chapter on generation is very brief and contains some notable omissions. For example, no mention is made of the use of synthetic crystals such as barium titanate, nor is the use of siren generators discussed for propagation in gases. Similarly, whistles of the resonant cavity and lip reverberation type are disclaimed for use with liquids. Work on such generators was carried out in Germany during the war and more recently in England, and there would seem to be a number of possibilities for this relatively simple method of generation.

In the last two chapters the author has kept strictly to the study of absorption and dispersion, and it is regretted that no data has been included on the physical effects produced in the medium. Cavitation is briefly mentioned and the book could have been infinitely more useful if a further chapter had been added on this very important aspect of ultrasonics.

Generally, the text is well presented and the mathematics used in the complex subjects of propagation and absorption are easily followed. A bibliography is included and the author has not made the common mistake of repeating references already available in other textbooks and articles. With the increasing interest that is now being shown in ultrasonics, the book forms an excellent bridge between the electronic engineer basically trained in electro-magnetic propagation and the worker in acoustics accustomed to thing in terms of particle movement.

A. E. Crawford

The Magnetic Amplifier

By J. H. Reyner. 119 pages. 72 figures. 1st Edition. Stuart and Richards, London, 1950. Price 15s.

FIRST impressions of this book are that it must be a little sketchy because it does not contain much of the rather tedious mathematical analysis which is found in learned papers on the magnetic amplifier. But reading shows that after the first chapter, which gives the beginner a qualitative idea of the construction and characteristics of transductors, there is an engineering treatment of all the points which a designer needs to watch. This is not to say that the book is comprehensive—for example three alternative linear approximations to the magnetization characteristic of iron are cited at the beginning of Chapter 3 and then one is used and the other discarded without further discussion. However, the points which are glossed over could on the whole be called "academic," and the design information includes a discussion of the relation between time-constant and gain. The slow response of the parallel-connected magnetic amplifier in comparison with the series type (a point which is often overlooked) is mentioned on p. 46, though on p.19 it is stated that "there is little to choose between these two arrangements."

A commendable feature is the use of graphical characteristics for the voltage/current relationship in a transductor, and the demonstration of a load-line technique for combining the characteristics of amplifier and load. Load-line constructions have proved indispensable for designing around the non-linear characteristics of a thermionic valve, and they ought to be equally applied to the non-linear design problems of magnetic amplifiers. The author also describes a fair selection of "technical tricks," including some polyphase circuits, and makes the point that high induced voltages in individual control windings can be avoided by using constructions in which a single control winding encircles two cores with opposite A.C. fluxes.

From the literary side, your reviewer would prefer a clear convention that a "transductor" is a current-current conversion device, i.e., a more or less complicated iron core with at least two windings on it, and a "magnetic amplifier" is the complete unit with rectifiers, feedback connexions, bias supply, etc.; and the index to this book would be improved by having more sub-headings to such entries as "power gain" (five page numbers) and "standing current" (six page numbers).

D. A. Bell

Atoms and Atomic Energy

By R. W. Hallows. 196 pp. Chapman and Hall, Ltd. 1950. Price 10s. 6d.

THIS book is a welcome addition to the series by R. W. Hallows, and is a simple explanation of the development of atomic energy. The author, in his preface, likens the development of the atom to a detective story, and the way in which it is unravelled in this book is equally thrilling.

A useful appendix called "Tools of the Trade" is included, and eight interesting plates show various aspects of the growth of atomic energy, and their application in the atomic bomb.

The book is well produced, and has many clear diagrams. It should appeal to a wide circle of readers, even those with little or no technical knowledge, as it is extremely readable.

16-mm Sound Motion Pictures

By W. H. Offenhauser. 592 pp., 123 illustrations, 30 tables. Interscience Publishers, Inc., New York. 1949. Price $10.0.

THIS book presents a readable guide of 16-mm Sound Motion Pictures, through all phases and aspects, including applications. Chapter headings include: Making a 16-mm picture, 16-mm film and its characteristics, emulsion problems, cameras and equipment, sound recording, editing, storage, procession, projection, colour, industrial applications and television and film.

It is clearly presented, with good illustrations, and should make interesting reading for all those concerned with this type of film.

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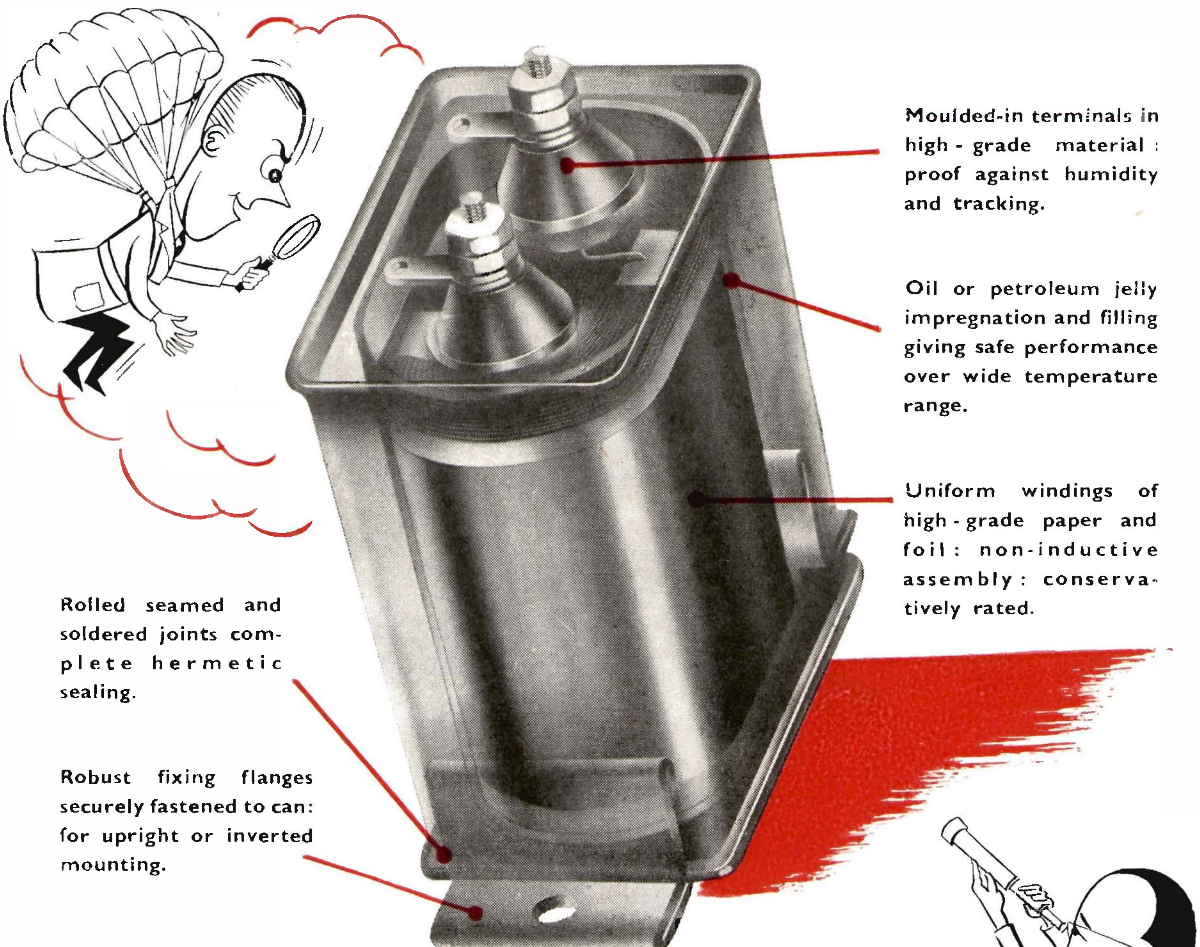

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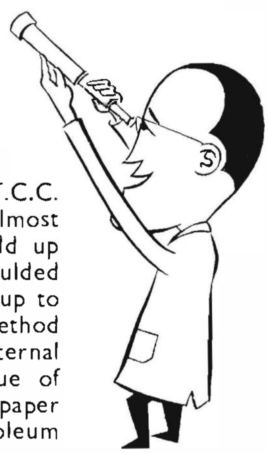

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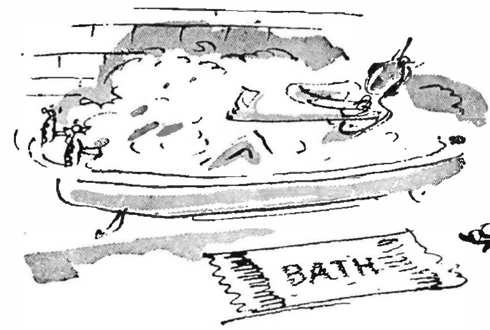

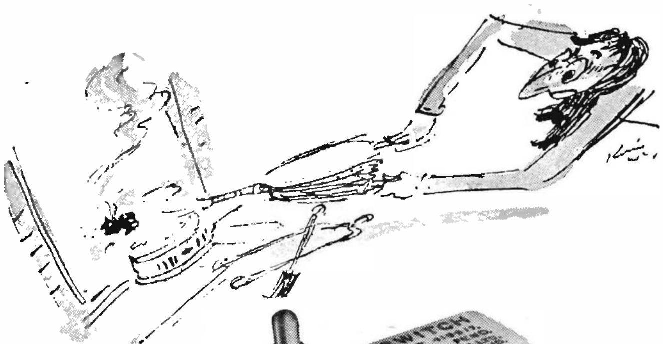

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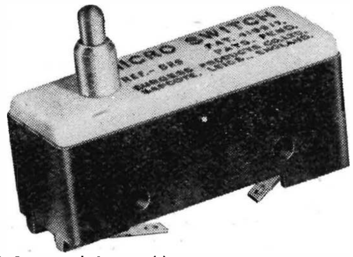

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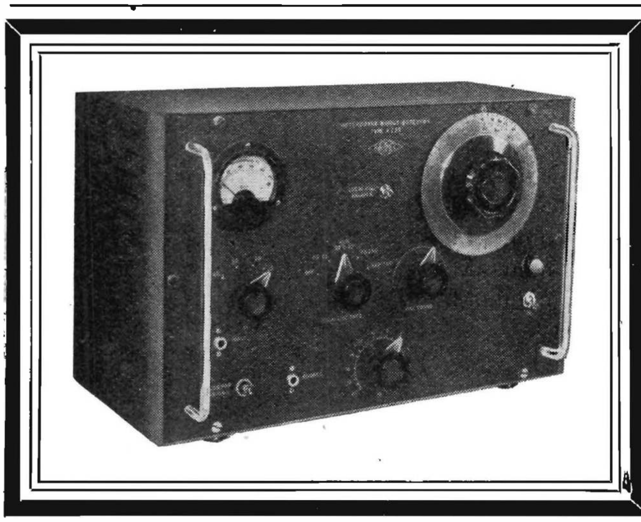

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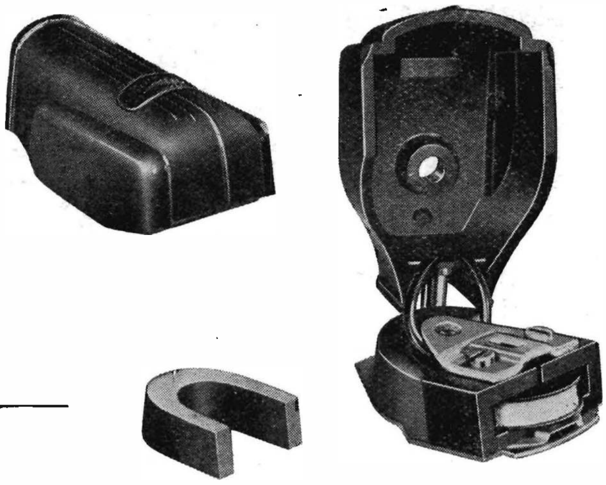

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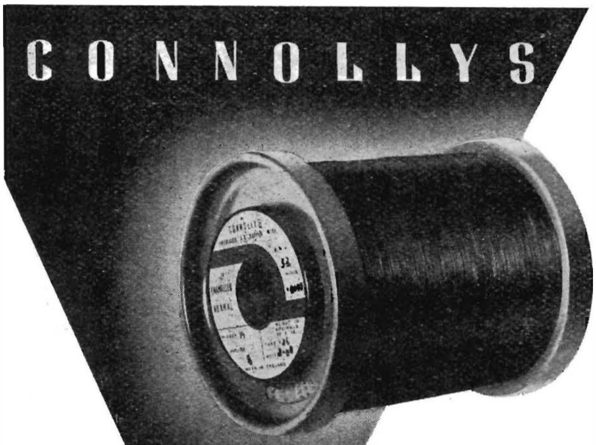

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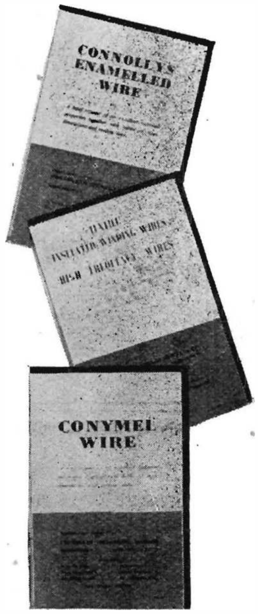

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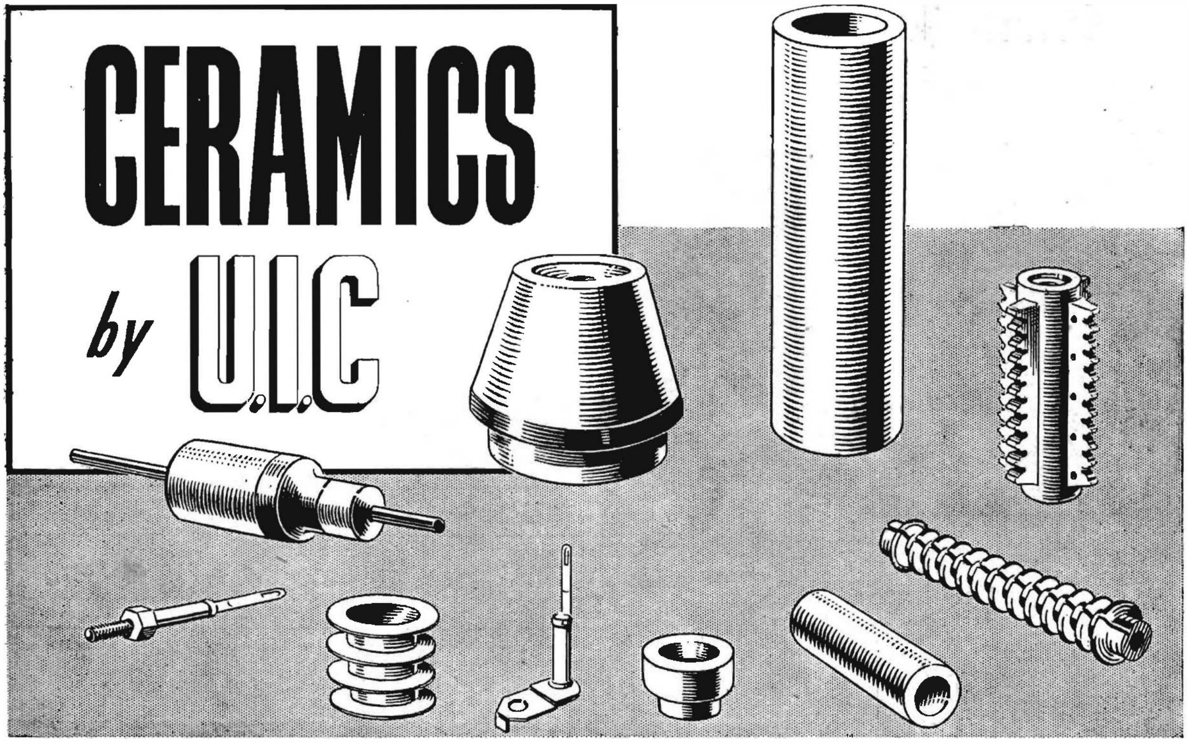

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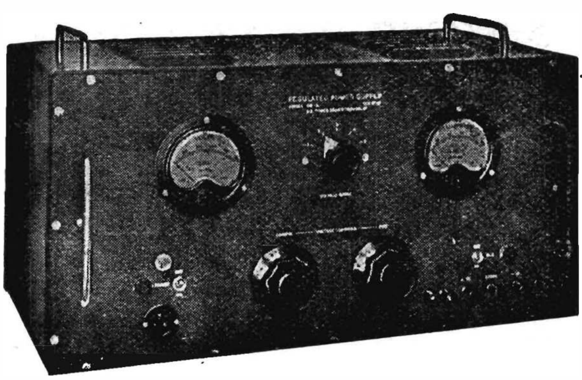

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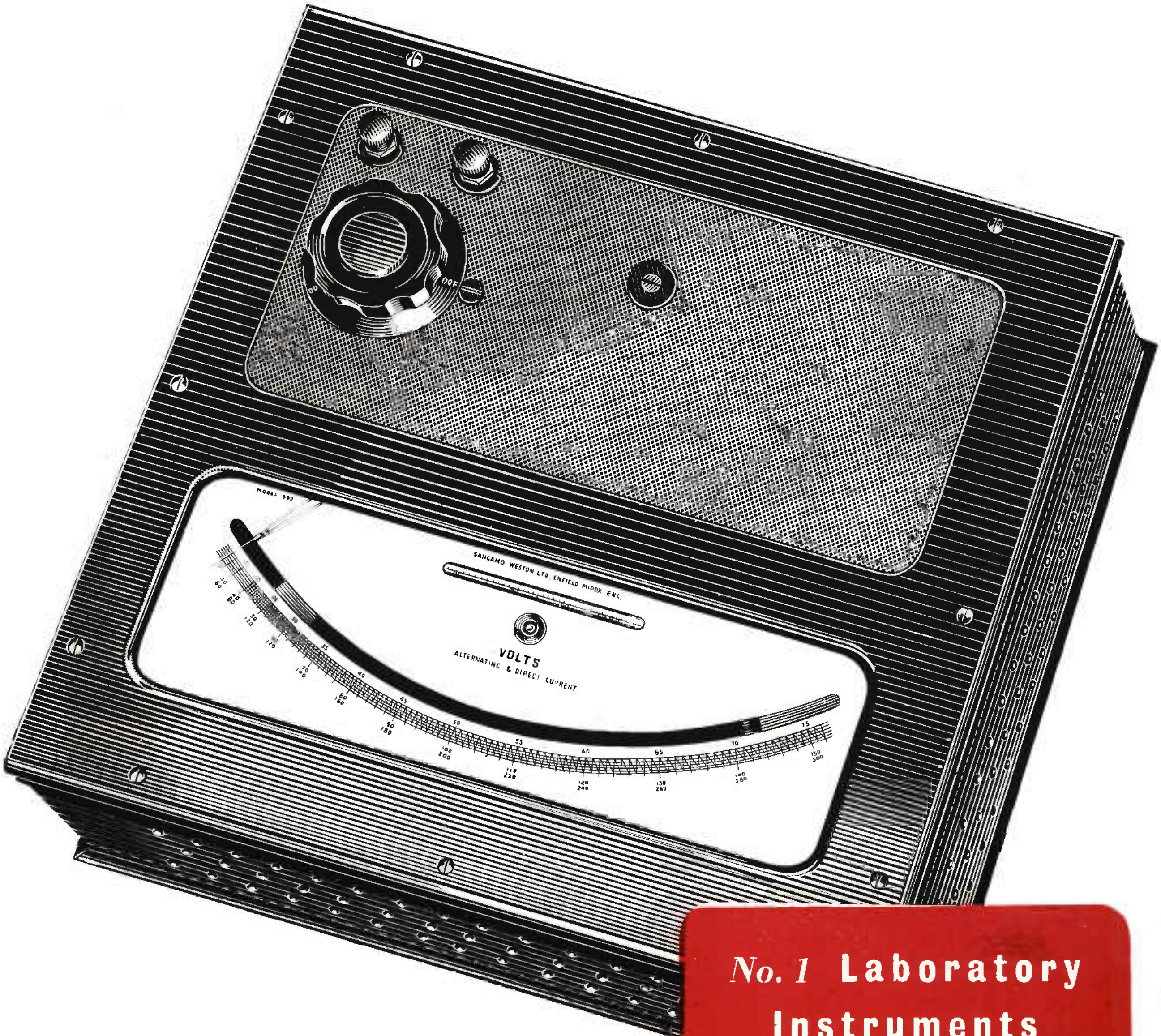
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