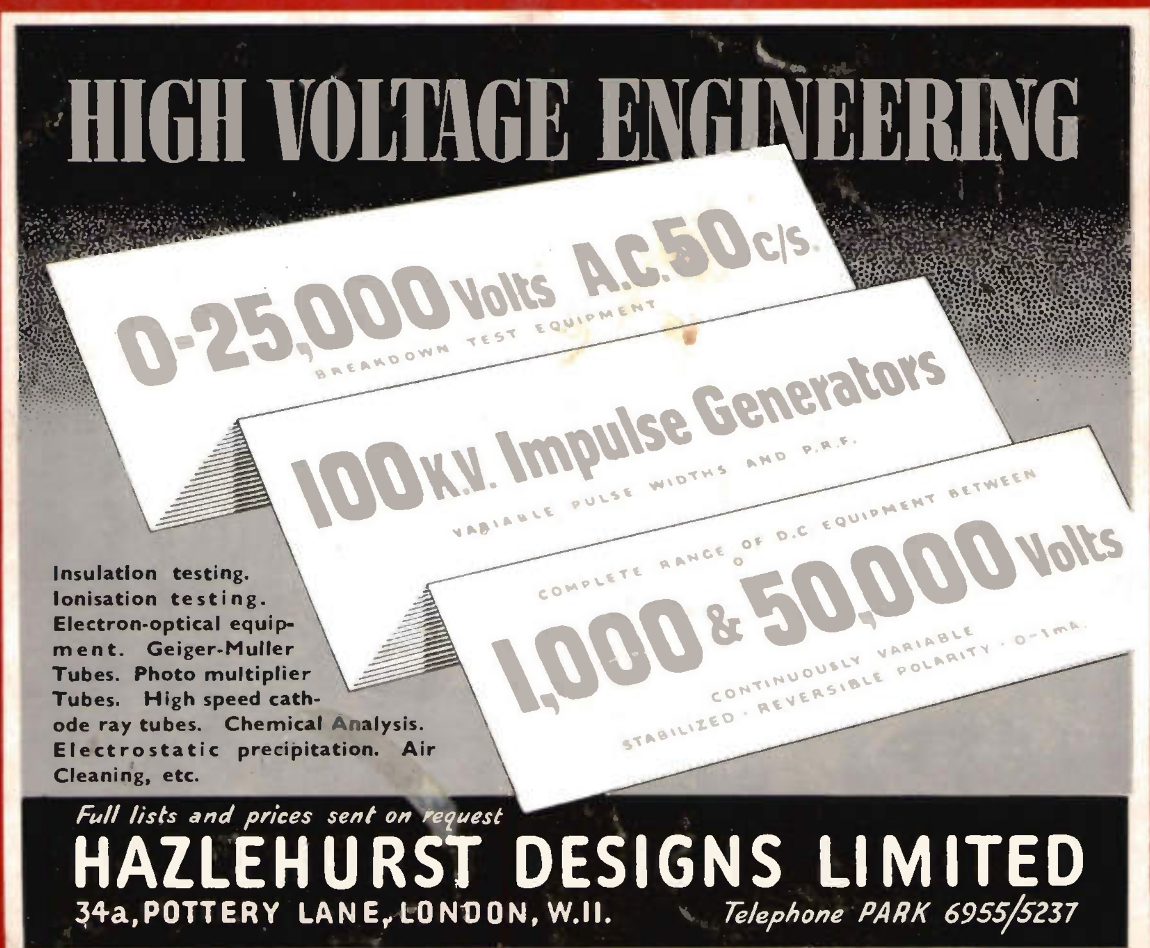
Electronic Engineering

FEBRUARY 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

B.B.C. invites applications for a post of Engineer in the Studio Section (Recording) of Planning and Installation Department, based in London. Applicants should have a good theoretical and practical knowledge of the principles involved in audio-frequency and sound-recording work.
A University Degree in Electrical Engineering, or equivalent qualifications, would be an advantage. The successful candidate must be prepared to spend a considerable amount of time away from London, as he will be required to plan and supervise the installation of sound-recording equipment at any of the Corporation centres throughout the country. Starting salary, £745 per annum (may be higher if qualifications and experience are exceptional), rising by annual increments on a five-year progression to £965 per annum. The successful applicant will become eligible for consideration for appointment to established staff (Contributory Pension Scheme) after two years' qualifying period. Applications, stating age, qualifications and experience, to reach Engineering Establishment Officer, Broadcasting House, London, W.1, within seven days. W 2661

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 £283-£510 per annum. Exceptionally well-qualified candidates may be considered for appointment in a higher grade within the salary range £470-£610 per annum. Hostel accommodation is available at some establishments. Applications, stating age and details of technical qualifications and apprenticeship (or equivalents) and workshop and drawing office experience, should be sent to Admiralty (C.E.II, Room 88), Empire Hotel, Bath. 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 2687

SITUATIONS VACANT

DEVELOPMENT ENGINEERS required by firm in N.W. London manufacturing an extensive range of industrial instruments and controls. Candidates should have a good theoretical background, preferably with a Degree, or equivalent, in Physics or Electrical Engineering, and in addition should have experience in one of the following : (*a*) Industrial instruments and process control. (*b*) Servo mechanisms. (*c*) Magnetic amplifier design. (*d*) Application of electronics to industrial measurements and control. The starting salary will be according to the experience of the applicant, ranging from £400 per annum for Junior Engineers, to £650 per annum for specially qualified applicants. Write Box No. W 2696.

PROTOTYPE WIREMEN required for producing highest grade television transmission and other equipment. Applicants should possess sound fundamental knowledge of both radio and television, together with some experience of layout and wiring of video equipment. Wiring to be of instrument standard and applicants must be capable of producing own component layouts. City and Guilds, High Nat. or similar qualifications, desirable, but comprehensive practical experience acceptable in lieu. Write, stating age, experience and salary required, to Cinema-Television Ltd., Worsley Bridge Road, Lower Sydenham, S.E.26. W 2700

ASSISTANT, with B.Sc., or equivalent, required for High Frequency Laboratory in Research Laboratories associated with the Cable Industry in North Kent. Reply Box No. W 2697.

JUNIOR ENGINEERS, interested in radio/radar and servo-mechanisms, are required in special English Electric Company laboratories, working on new defence project. Preference given to applicants with Ordinary or Higher National Certificate in Electrical Engineering. Progressive post. Commencing salary, £400-£600 per annum, according to qualifications. Write, giving details and mentioning Ref. 815, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2705

EX-R.E.M.E. Officer or Mechanical Engineer, with organising ability, required to assist in the organising of light engineering constructional work, and supervise field trials of a novel device. Apply, giving full details, and mentioning Ref. 487, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2706

HOUSE (married accommodation) available for Senior Engineer for experimental work on servo-mechanisms required for important defence project in special English Electric Company laboratory. Permanent post. Good experience in servo loop design essential. Commencing salary, £700-£900 per annum. Apply, giving full details and quoting Ref. 844A, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2707

WANTED, experienced Electronics Engineer, to take charge of investigations with effects of vibration or electronic gear and development of anti-vibration measures, in special English Electric Company laboratory. Starting salary, £600-£800 per annum, according to qualifications. Apply, giving full details and quoting Ref. 850, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2708

DRAUGHTSMEN and Designers are required by the Research Laboratories of the General Electric Co. Ltd., Wembley, Middlesex, for work of great national importance in the field of electronics. Preference will be given to candidates aged 21-30, who have had practical workshop or laboratory experience. Attractive starting salaries will be paid. Applications should be sent in writing to the Personnel Officer (Ref. GBLC/411) and should give details of age, qualifications and experience. W 2703

MARCONI'S WIRELESS TELEGRAPH Co. Ltd. have vacancies for Technical Assistants for contract work in their Broadcasting Division. Applicants should have had works' experience, preferably in the planning and progressing of production. Some experience of broadcasting or television equipment would be an advantage. Successful candidates will be paid a salary in a grade which rises to a maximum of £515 per annum. A Staff Pension Scheme is in operation. Please write, giving full details and quoting Ref. 847, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2702

ELECTRONIC ENGINEER, with Physics or Engineering Degree, capable of lecturing semi-technical and technical students on theory and practice of radar, required by large Light Engineering Company, East London district. Applications, in writing, giving details of age and qualifications, to Box No. W 2701.

RADIO MECHANIC wanted for development of industrial electronic equipment. Teddington area. Write, stating experience and salary required, to Box No. W 1242.

RADIO AND TELEVISION Development Engineers required by large Company in East London area. Applicants should have technical qualifications and several years' laboratory experience of radio development work. Permanent positions with good prospects. Kindly state full details of qualifications and experience, with age and salary required, to Box No. W 2710.

E.M.I. ENGINEERING Development Limited require experienced Electronic Engineers, including team leaders, for the development and design of radar equipment. Applicants should have a sound technical training with a degree, or equivalent qualification, and several years' experience in this field ; a thorough knowledge of microwave technique and ability to originate circuitry is essential. The appointments are for permanent pensionable staff and carry a good salary and excellent prospects. Applicants should write, quoting ED/34, and give full details to Personnel Department, E.M.I. Engineering Development Limited, Blyth Road, Hayes, Middlesex. W 2709

HOUSE (married accommodation) available for Senior Engineer for experimental work on radar, radio and/or electronics for important defence project in English Electric Company laboratory. Honours Degree preferable. Commencing salary, £700-£900 per annum. Apply, giving full details and quoting Ref. 456C, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2704

A VARIED and interesting opportunity occurs for versatile Physicists or Electronic Engineers who wish to apply scientific principles to a wide range of problems in the Engineering Industry. Applications are invited for posts in the West London area, and should give full details of education, qualifications, experience and salary required, to Box A.E.219, c/o Central News, 17, Moorgate, London, E.C.2. W 2712

RADAR ENGINEERS required by London firm specializing in Marine Radar. Applicants should be ex-Army Staff Sergeants or Navy P.O. Grades, with experience of Service Radar and passed long Radar Course. Apply Box No. W 2711.

A RADAR Engineering Post offering great scope for advancement in well-paid and interesting work, is available immediately. Applicant must be competent and well-qualified engineer, with sound and broad experience in modern design techniques, who can quickly prepare himself for a senior position, involving responsible development work in the field of high voltage pulse techniques. Applications, giving age, qualifications and experiences, to The Radar Laboratory, Decca Radar Ltd., Shannon Corner, New Malden, Surrey. W 1243

FERRANTI LIMITED have vacancies at their Radio Works, Moston, Manchester, for : (*a*) A young Graduate in Physics or General Science, to assist in the General Physics Section of the Laboratory (Reference G.P.). (*b*) An Honours Graduate in Physics, interested in Thermionic Emission, Electron Optics, Vacuum Techniques and General Electronic Process work, to assist in the Physical Laboratory on production control of cathode-ray tubes (Reference, C.R.P.). Liberal salary, according to qualifications and experience. Pensionable appointment. Application forms from the Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote appropriate reference. W 2714

PHYSICAL CHEMIST or Physicist with a good Honours Degree, is required for fundamental work on semi-conductors. Graduate with 3-5 years' experience in this or a related field will be preferred. Some " Solid Physics " experience is desirable. Applications, in writing, should be sent to the Personnel Officer (Ref. GBLC/447), Research Laboratories of The General Electric Co. Ltd., North Wembley, Middlesex, stating age, academic record and post-graduate experience. W 2717

A TECHNICAL ASSISTANT is required with considerable experience of the Wire and Cable Industry for light current and electronic engineering. The position involves a wide knowledge of specifications, the ability to prepare and maintain a classified index of cables, and the experience to assist designers in choosing cables. Laboratory experience in testing cables would be advantageous. Apply, giving age, fullest details of experience, etc., to Personnel Department, E.M.I. Engineering Development Ltd., ED/B, Blyth Road, Hayes, Middlesex. W 2718

THE MULLARD RADIO VALVE Company require : (*a*) Senior Research Physicist for work in connexion with research and development on special valves. 1st or 2nd Class Honours Degree and previous experience of this type of work essential. Salary according to age and experience. (*b*) Three Physicists or Engineers for research and development on special valves. 1st or 2nd Class Honours Degree and previous research experience preferred. Applicants should not be over 25 years of age. Commencing salary according to age and experience, but will not be less than £450 per annum for week of 39½ hours. (*c*) Six Laboratory and Technical Assistants, to assist in the production and development of valves. Inter B.Sc. or equivalent and previous experience preferred. Commencing salary not less than £325 per annum for week of 44 hours. Write for application forms, quoting Ref. (*a*), (*b*) or (*c*), to Personnel Officer, Mullard Radio Valve Company Limited, New Road, Mitcham Junction, Surrey. W 2713

LABORATORY ASSISTANTS and Radio Mechanics with Ordinary or Higher National Certificate or City and Guilds Full Technological Certificate, are required at Stanmore, Middlesex, for work with research engineers engaged on new developments. Experience in a radio or television laboratory and ability to construct wire and test communications equipment and to use machine tools are essential. Replies will be sent to all applications sent to the Personnel Officer, Research Laboratories of The General Electric Co. Ltd., East Lane, North Wembley, Middlesex (Ref. GBLC/445), which give details of age, qualifications and experience. W 2715

GRADUATE PHYSICISTS and Engineers are required by the Research Laboratories of The General Electric Co. Ltd., North Wembley, Middlesex, for : (*a*) A research group concerned with microwave valves. Applications are invited from those interested in both the theoretical and experimental aspects of the fundamental problems concerned with the interaction of electrons with electro-magnetic fields. (*b*) Work concerning problems of experimental valve constructional techniques. A man with experience in this field would be preferred. (*c*) Problems of waveguide transmission. A sound theoretical knowledge of this field of work is required, together with an interest in the engineering applications. Candidates should write to the Personnel Officer (Ref. GBLC/447), giving age, qualifications and experience. W 2716

UNITED SHEFFIELD HOSPITALS. Royal Infirmary, Sheffield. Applications are invited from suitably qualified persons for the post of Senior Technician to the Department of Electro-Encephalography, shortly to be set up at the Royal Infirmary. The salary paid will be in accordance with qualifications and experience of candidate, who should possess a full knowledge of the working of the electro-encephalograph and be able to undertake the necessary recordings. Applications, together with copies of testimonials, to be addressed to the undersigned forthwith. Frank Hart, Superintendent, Royal Infirmary, Sheffield, 6. W 1248

APPLICATIONS are invited for the post of Electronic Assistant in the University Mathematical Laboratory for work in connexion with electronic calculating machines. Candidates, who should be over 21 years of age and have completed National Service, should have had some experience in Electronics and should be able to read circuit diagrams and wire-up chassis. The commencing wage will be within the range £234-£338 by £13 per annum, according to experience and age. Applications should be sent at once to the Director, University Mathematical Laboratory, Free School Lane, Cambridge. W 1237

ELECTRONICS TECHNICIAN wanted by University Department in a Medical School to assist with the design, construction and maintenance of apparatus for electro-physiological research. Must have wide knowledge of audio and radio frequency techniques, cathode-ray oscillography and photographic recording. Workshop experience an advantage. Salary in range £390-£465, according to experience. Family Allowance and Superannuation. Apply, in writing, to the Secretary, Department of Physiology, Middlesex Hospital Medical School, London, W.1. W 1249

LABORATORY ASSISTANT, B.Sc. Degree standard, Electronic Engineering, industrial experience not necessary, to train in laboratory of a firm of high voltage Engineers. Progressive post for right candidate. Salary according to qualifications. Please ring PARK 6955 or write to Box No. W 2719.

RESEARCH LABORATORIES of The General Electric Co. Ltd., North Wembley, Middlesex, require a Graduate in Physics or Engineering with 3-5 years' experience in work of an electronic nature for research on all aspects of receiving valve applications, including investigations of performance at high and low frequencies, standardisation of new types, noise, microphony, etc. Previous experience in this field would be an advantage. Applications, giving details in writing of age, qualifications and experience, should be sent to the Personnel Officer (Ref. GBLC/475) W 2720

PHYSICAL CHEMIST of Electro-Chemist required to build up and operate a small production unit for the manufacture of a new type of electrolytic condenser. Previous experience of electrolytic condenser manufacture and testing would be an advantage. The laboratory is located in Northamptonshire. State full details to Box No. W 2721.

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

RADIO AND RADAR Mechanics. Ferranti Limited have additional vacancies in their Edinburgh Works for fully qualified men capable of constructing and testing electronic equipment. At least five years' practical experience and City and Guilds qualifications desirable. Interesting non-repetitive work offering scope for initiative. Starting wage according to qualifications. Apply, quoting Ref. R.M., and giving full details of experience, etc., to the Personnel Officer, Ferranti Ltd,. Ferry Road, Edinburgh. W 130

ELECTRONIC TEST ENGINEERS (2) for interesting post development work, including the design of test equipment. Should have Degree in Electrical Engineering, or equivalent, and preferably experienced in electronics. Apply, quoting Ref. TE., and giving full details of training, qualifications and experience, to the Personnel Officer, Ferranti Ltd., Ferry Road, Edinburgh. W 2673

MARCONI'S WIRELESS TELEGRAPH Co. Ltd. invite applications from persons interested in joining teams which will spend a considerable time in various parts of the world carrying out wave propagation experiments leading to the selection of sites for the erection of wireless stations. Preferably applicants should possess a University Degree, but consideration will be given to those possessing other qualifications. Selected applicants will be trained under expert guidance in this country before taking up duties, and will be employed in the laboratory during intervals of home service. In addition to normal home pay, successful applicants will receive an overseas allowance and liberal expenses whilst abroad. The Company operates a Staff Pension Scheme. Apply, quoting Ref. 833, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2672

TECHNICAL Writer required for leading company in London engaged in radio, radar and electronics field with international business. Applicants must have ability to extract data from research and design staff and to compile technical manuals, instruction books, and to write clearly on technical subjects for editorial purposes. The position offers wide scope for initiative and the opportunity of building up an efficient technical information department. Previous experience in this field essential. Please write fully in confidence, stating technical qualifications, age, salary required and all details, to Ref. CJ. Box No. W 2671.

ENGINEER, capable of initiating production of high stability carbon resistors, or precision condensers, required. Share in enterprise offered to right man. Write, stating experience, etc. Box No. W 1235.

ELECTRICAL ENGINEERS wanted by large firm in the Manchester area to specialise in the laboratory development of servo-operated and process control instruments. Apply, in writing, stating age, qualifications, experience, salary required, etc., marking envelopes "Meter," to Box No. W 2669.

WELL-KNOWN Firm of Precision Engineers and Scientific Instrument Makers requires Research Physicists and Engineers for the Physics and Electronic Circuits Division of their Research Laboratories situated on the northern outskirts of London. Vacancies exist for : (1) A Senior Research Engineer, age 30 to 40, starting salary £1,000 to £1,500 per annum, according to qualifications and experience. (2) Research Engineers and Research Physicists, age 25 to 30, to take charge of small research groups, starting salary £700 to £1,000, according to age and experience. (3) Junior Research Physicists and Engineers, age 21 to 26 ; starting salary £350 to £700, according to age and experience. Candidates for posts (1) and (2) are expected to have an Honours Degree in Physics or Engineering and to have had research experience. For one of the posts under (2) experience of research in advanced circuit techniques is required ; for other posts, particular research experience is not important but the research to be carried out will be mainly on the properties of materials. Candidates for posts under (3) are expected to have an Honours Degree or research experience. All posts will be permanent and a Superannuation Scheme, to which the firm contributes, will be available to those successful candidates who wish to join. Applications must be made in writing by 14th February, 1951. Before appointment candidates will be expected to attend an interview in the vicinity of London. Reasonable travelling expenses will be paid. Box No. W 2668.

MARCONI'S WIRELESS TELEGRAPH Co. Ltd. have vacancies for Junior Engineers in the Television Demonstration Section of their Broadcasting Division. Applicants should preferably have had experience in the installation, operation and maintenance of television or film production equipment. Successful candidates will be paid a salary in a grade which rises to a maximum of £590 per annum. Subsequent promotion will be by transfer to other sections of the Division. The Company operates a Staff Pension Scheme. Please write, giving full details, quoting Ref. 467A. to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2665

ENGLISH ELECTRIC require a Technical Representative for the Birmingham area. Candidates should have good experience of industrial electronic equipment and be resident in the Birmingham area. Previous commercial experience in this field is desirable. Car provided. Write, giving full details of previous experience, Quoting Ref. 356E, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, Westminster, S.W.1. W 2666

MARCONI'S WIRELESS TELEGRAPH Co. Ltd. have vacancies for Project Engineers in their Broadcasting Division. Applicants must have experienced in installation, operation and maintenance of broadcasting or television transmitting or studio equipment. Some design experience would be an advantage. Successful candidates will be paid a salary in the grade of £440 to £880 per annum, the starting point being determined by the applicant's qualifications and experience. The Company operates a Staff Pension Scheme. Please write, giving full details, quoting Ref. 466A, to Central Personnel Services, English Electric Co. Ltd., 24-30, Gillingham Street, London, S.W.1. W 2667

A COMPANY of international repute have a vacancy for a communications specialist with experience in the planning of H.F. and V.H.F. radio networks in either the Civil or Aeronautical spheres. The post is primarily a sales one, but some technical experience is essential. The applicant should have access to Government and similar authorities likely to be interested in such equipment in both this country and overseas. This is a senior post with a commensurate salary. Write, in confidence, full details of experience, age and salary required. Our staff have been informed of this vacancy. Box No. W 2656.

CLASSIFIED ANNOUNCEMENTS
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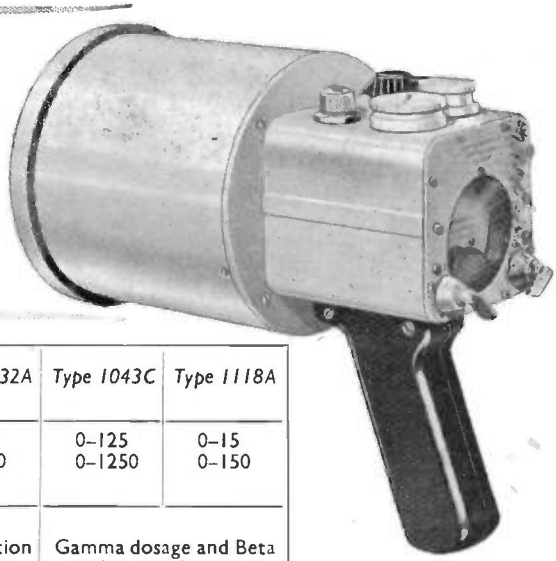
EKCO RADIATION MONITOR Type 1132A



This Monitor is designed for use with X-Rays and will give accurate indication of dosage of soft radiation. It is self-contained and portable. There are other Ekco Monitors of similar design for Gamma dosage and Beta qualitative detection, as listed on right.

	Type 1132A	*Type 1043C*	*Type 1118A*
Range mR/hr	0–15 0–150	0–125 0–1250	0–15 0–150
Use	X-radiation 10KeV upwards	Gamma dosage and Beta qualitative detection	

E. K. Cole Ltd. can supply a complete range of equipment for the radio-chemical laboratory. Write for catalogue giving full specifications and prices.

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The illuminated graticule and single shot camera attachment gives clear records and accurate measurements.

STABLE TRACES

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TIME BASE RANGES

Calibrated sweep velocities from 2 in. per sec. to 2 in. per u sec. Triggered or continuously running.

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Response, Maximum Gain and Sensitivity

0-20 *K/cs.*	0-2 *Mc/s*	0-10 *Mc/s*
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Phase to frequency ratio constant. Perfect square wave definition within the limitations of each frequency range.

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ATTRACTIVE opportunities are available at the Research Laboratories of The General Electric Co. Ltd., North Wembley, Middlesex, for Physicists and Engineers aged 25-30, with at least two and preferably five years' experience in research or development work in one of the following fields: (*a*) Microwave aerial and feeder systems. (*b*) Microwave transmitters or receivers. (*c*) Generation and handling of special waveforms as used for television, pulse multiplex or computers. These positions are especially suitable for men with good academic qualifications, experimental ability and a flair for original work. Good starting salaries with excellent prospects. Applications should be sent to the Personnel Officer (Ref. GBLC/209). W 2670

PHYSICIST required by Radio Manufacturer in London area for work in connexion with acoustic problems. Applicants must have Degree in Physics and some development experience. The successful applicant will be required to start up and run new laboratory. State full details of qualifications and experience with age and salary required, to Box No. W 2654.

SALES MANAGER required to act as controller of overseas agencies for large light engineering company with offices situated in the London area. Applicants should have basic training in engineering and some electronic experience would be an advantage. Knowledge of overseas markets and experience of export sales is essential. Applicants should give the fullest details of past experience with age and salary required to Box No. W 2655.

SENIOR PHYSICIST required for Development Laboratory situated in a country district of Essex. Applicants must have Degree in Physics and should have development experience on ceramics, preferably covering measurement of electrical properties. Housing accommodation will be available for the successful applicant. Please state full details of qualifications and experience with age and salary required to Box No. W 2657.

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

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

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

TELEVISION DEVELOPMENT ENGINEER, with at least four years' laboratory experience in the development of vision and sound receivers, required to fill a vacancy in a new section. Applicants should have commercial experience in the design of such equipment for production. Apply in writing, giving age, qualification, details of experience, and salary required, to Cinema-Television, Ltd., Worsley Bridge Road, Lower Sydenham, S.E.26. W 2653

COMMUNICATION RECEIVERS. Engineer required with sound practical knowledge to take charge of small section. Full particulars in writing of past experience, and salary required, to Box No. W 2690.

RUNWELL HOSPITAL, near Wickford, Essex. Recordist for Electro-encephalographic Department required. Salary £300 to £350 per annum, according to experience. Applications should be sent to the Physician Superintendent. W 2660

ATTRACTIVE and interesting openings for Graduate Physicists and Engineers, age 21-30, are available at the Research Laboratories, The General Electric Co., Ltd., North Wembley, Middx., in the following fields: (*a*) Radiocommunications and Telephony; (*b*) Waveguides; (*c*) X-ray Analysis; (*d*) Transmitting and Receiving Valves; (*e*) Cathode Ray Tubes; (*f*) Vacuum Physics; (*g*) Illumination; (*h*) Domestic Heating Appliances. Vacancies exist for men and women with and without industrial experience since leaving the university. Good starting salaries will be paid and prospects will be excellent. Candidates should send details of their age, qualifications and record in writing to the Personnel Officer. (Ref. GBLC/122.) W 2659

QUALIFIED JUNIOR PHYSICIST required for experimental work on cathode-ray tubes and allied vacuum tubes. Age 21-28. Previous experience of vacuum work desirable, but not essential. Write, stating age, experience and salary required, to Cinema-Television, Ltd., Worsley Bridge Road, Lower Sydenham, S.E.26. W 2651

TECHNICAL ASSISTANT required for development of electronic test gear for Vacuum Tube Department. Qualifications up to Inter B.Sc. or Ordinary National, City and Guilds No. 2 or 3. Write, stating age, experience, and salary required, to Cinema-Television, Ltd., Worsley Bridge Road, Lower Sydenham, S.E.26. W 2652

PLANNING ENGINEERS required. Intelligent and energetic men to assist in the planning of development work on electronic apparatus. One appointment will be as assistant manager in the department. Some practical experience in this field is essential since the duties will include, planning, estimating and forecasting. Initiative in investigating all aspects of the work with a flair for lucid presentation of the findings will be important qualities. Adequate salaries will be paid proportional to age and qualifications. Applicants should send full details of age, education and experience, and quote ED/31 to Personnel Department, E.M.I. Engineering Development Limited, Blyth Road, Hayes, Middlesex. W 2663

INSTRUCTOR in Radio and Television Servicing required for the Manchester area. In addition to taking charge of short practical courses in television servicing, this instructor should be able to lecture to the level of the City and Guilds Radio II and Radio III Examinations. The commencing salary depends on experience and qualifications and will be in the range of £450 to £650 per annum. Applications, with the names and addresses of two persons to whom reference may be made, should be sent to: The Principal, E.M.I. Institutes, Ltd., 10, Pembridge Square, London, W.2. W 2693

TECHNICAL WRITERS (female) required to prepare and edit reports and handbooks for publication. Qualifications: A good general training in electronics with practical experience of electronic equipment desirable; marked critical faculty, and ability to write clear English. Applicants should write, giving full details and quoting ED/19, to Personnel Department, E.M.I. Limited, Blyth Road, Hayes, Middlesex. W 2695

E.M.I. Engineering Development Limited have a number of vacancies for Engineers and Senior Engineers on interesting development work in various electronic engineering projects. The posts are for permanent pensionable staff and offer good prospects. Qualifications: A Degree in Physics or Engineering or equivalent, together with several years design or specialised experience in the following fields:—(*a*) L.F. Equipment; (*b*) Television Equipment; (*c*) Microwave Techniques; (*d*) Pulse Techniques; (*e*) Servo mechanisms; (*f*) Test Gear Design; (*g*) Inspection. Applicants should write giving full details of experience and type of work required, and quote ED/33, to Personnel Department, E.M.I. Engineering. Development, Ltd., Blyth Road, Hayes, Middlesex. W 2691

EXPERIENCED Electronic Engineers required for interesting development work. Qualifications: A good Honours Degree in Physics or Engineering with several years' design experience, including radar equipment or specialized experience on centimetric techniques. The appointments are for permanent pensionable staff and offer good prospects. Applicants should write, giving full details and quote ED/32, to: Personnel Department, E.M.I. Engineering Development Limited, Blyth Road, Hayes, Middlesex. W 2662

ASSISTANT to Engineer in charge of the Development Laboratory required by large light engineering company in London area. Applicants should be technically qualified and must have sound radio and electrical knowledge. Experience in the design for mass production of light intricate electrical and mechanical instrument assemblies, and experience in the control of drawing office and laboratory staff is essential. The appointment is a senior one and a commensurate salary will be paid. Kindly state full details of qualifications and experience, with age and salary required to Box No. W 2664.

E.M.I. Institutes. Principal: Professor H. F. Trewman, M.A.(Cantab.), M.I.E.E., M.I.Mech.E., M.Brit.I.R.E. The introduction of our four-year course has created vacancies for lecturers in Electronic and Telecommunications Engineering. Applicants for these posts should be graduates in Physics or Electrical Engineering and should possess industrial experience, with preferably some instructional experience. Applicants should be between 23 and 30 years of age. The commencing salary depends on qualifications and experience and will be in the range of £510-£730 per annum. Applications, stating age, qualifications and experience, with the names and addresses of two persons to whom reference may be made, should be sent to: The Principal, E.M.I. Institutes, Ltd., 10, Pembridge Square, London, W.2. W 2694

DYNATRON RADIO require highly experienced Radio and Television Service Engineer. First-class applicant with pleasing personality, and a good driver only need apply: Personnel Manager, Dynatron Radio, Ltd., Ray Lea Road, Maidenhead, Berks. W 1238

REQUIRED by the British Telecommunications Research. Ltd., at their research and development laboratories in Bucks., several senior radio communication engineers for project work in the V.H.F. and U.H.F. fields. Salary range £400 to £800 per annum. Application forms available from the Senior Radio Engineer, B.T.R., Ltd., Taplow Court, Taplow, Bucks. Suitable applicants will be invited for interview. W 2692

ADMINISTRATIVE ENGINEER with experience of technical correspondence and preparation of contracts required by department of Midlands firm engaged in electronic control equipments and R.F. heating. Salary £400-£600 per annum according to experience. Write giving details of age and experience mentioning reference HBG to Box No. W 2685.

ELECTRONIC ENGINEER required for development work by expanding industrial electronic team of well known manufacturing company. Previous experience of servo mechanisms and industrial process control together with Degree of H.N.C. essential. Write giving full details quoting reference GBH to Box No. W 2684.

MARCONI'S WIRELESS TELEGRAPH Co. Ltd., have vacancies for two engineers for work on VHF Development. Applicants for the first post must have good practical knowledge and experience on VHF Low Power Transmitters. For the second post, experience on Multiplex Channelling Audio and/or Video is required. Applicants must be familiar with problems on linearity, distortion, etc., and a knowledge of centimetric techniques would be an asset. Salary will be not less than £650 per annum and may be higher for candidates with outstanding qualifications and experience. The Company has a Staff Pension Fund. Please apply giving full details, quoting ref. 822, to Central Personnel Services, English Electric Co., Ltd., 24-30 Gillingham Street, London, S.W.1. W 2682

ELECTRONIC Development Engineers. Senior and Junior Electronic Engineers required for design and development work on interesting new projects. Degree or Higher National Certificate essential. Good salary and excellent prospects. Pension Scheme. State age, qualifications and experience to Personnel Manager, Fairey Aviation, Company, Ltd., Hayes, Middlesex. W 2681

CLASSIFIED ANNOUNCEMENTS
continued on Page 6

ASSISTANT Mechanical Engineer required by large well known firm to undertake mechanical design of interesting new electro mechanical equipments. The work will be varied and the prospects good. Apply quoting ref. DIH to Box No. W 2686.

NELSON RESEARCH Laboratories, English Electric Co., Stafford, have vacancies in their laboratories for men interested in experimental and theoretical work on small transformers and other allied iron core devices. This work will include the study of the behaviour of transformers, etc., under transient and steady A.C. conditions. Preference given to men with good Honours Degree in Physics or Engineering, interested in experimental work. Experience in this field desirable but not essential. Salary according to qualifications. Apply, stating age, qualifications and experience, quoting Ref. 821, to Central Personnel Services, English Electric Co., Ltd., 24-30 Gillingham Street, London, S.W.1. W 2679

RADAR, Radio and/or Electronics Senior Development Engineer wanted for work on important defence project in special English Electric Company Laboratory. Salary, £600-£900 per annum, according to experience. Write, giving details of qualifications and previous experience, mentioning Ref. 456A, to Central Personnel Services, English Electric Co., Ltd., 24-30 Gillingham Street, London, S.W.1. W 2678

TEST ENGINEERS required for design and manufacture of apparatus for production testing of Radar, Communications, and Electronic Equipment. Salary according to qualifications and experience. Full details to the Personnel Manager, E. K. Cole Ltd., Malmesbury, Wilts. W 2676

E. K. COLE LTD., have vacancies in their Electronics 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 2677

SCIENTIFIC GLASSBLOWER for Vacuum Physics Laboratories, experienced in high vacuum work and knowledge of glass and metal seals an advantage but not essential. Interesting work in ideal conditions and surroundings. Permanent staff position. Apply, stating salary expected and giving full details of training, qualifications and experience, to Personnel Officer, Ferranti Ltd., Ferry Road, Edinburgh. W 2674

VACANCIES exist for Electro-Mechanical Designers used to engineering the mechanical side of communications and similar projects, and also associated with heavy mechanisms. A good degree on Mechanical and Electrical Engineering or similar qualification is desirable as well as several years' experience in a Laboratory or Factory design department. Salary according to qualifications. Apply to Personnel Officer, Mullard Electronic Research Laboratory, Salfords, Nr. Redhill, Surrey. W 2630

HIGH FREQUENCY Induction Heating Applications Engineer required by progressive and expanding company specialising in the manufacture of high frequency equipment. Experience in induction heating essential and a good knowledge of metallurgy would be considered as an additional qualification. The position offers excellent opportunities for advancement to a really energetic man having the requisite experience. Write giving experience and salary required to Box No. W 1213.

FERRANTI LIMITED have vacancies in their Radio Works, at Moston, Manchester for Radio/Television Design Engineers, both senior and junior. Generous scale of payment, extending liberally into the four figure range, according to qualifications and experience. Permanent staff, appointments with superannuation benefits. Forms of application from The Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference R.E. W 2617

INTERESTING vacancies exist with the Nelson Research Laboratories of the English Electric Co. Ltd., for university trained electronic engineers or physicists with an interest in the design of special circuits for computing machines. These vacancies are at Stafford and in the London area and offer scope for original work in this interesting field. Write giving full details mentioning reference 305A to Central Personnel Services, English Electric Company Limited, 24-30, Gillingham Street, London, S.W.1. W 2621

RADIO VALVE ENGINEERS. The M.O. Valve Company have vacancies for qualified engineers in connection with the development manufacture and application of radio valves. Please apply by letter stating particulars and salary required to Personnel Department. The M.O. Valve Co., Osram Works, Brook Green, Hammersmith. W 2624

COIL WINDER required for interesting development work on a wide variety of coils and transformers. The applicant should have had at least three years experience of factory methods on small tranformers and wave wound coils. A knowledge of design and testing methods would be an advantage. Staff appointment, salary according to qualifications. Apply to Personnel Officer, Mullard Electronic Research Laboratory, Salfords, Nr. Redhill, Surrey. W 2629

A VACANCY occurs for a Senior Draughtsman of at least H.N.C. standard for layout work, on interesting electro-mechanical projects. Salary according to qualifications. Apply to Personnel Officer, Mullard Electronic Research Laboratory, Salfords, Nr. Redhill, Surrey. W 2628

AN EXPERIENCED Valve Engineer is required for employment at Chelmsford. Applicants should be 25-35 years of age, qualified engineers and preference will be given to those with previous design or production experience of small transmitting valves. Write giving full details of experience mentioning ref. 497C to Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, London, S.W.1. W 2632

APPLICATIONS are invited from men aged 21-40 years for work of a permanent nature which offers considerable scope for advancement. Applicants should have experience in the development and construction of Laboratory Test or Instrumentation Equipment or Sub-Miniature U.H.F. Gear. Ordinary or Higher National Certificate or C. and G. Telecommunications (Parts II and III) desirable. Salary commensurate with qualifications and experience. Apply to Box No. W 2637.

MURPHY RADIO LTD., having recently expanded their Electrical Design Department invite applications from television and radio engineers having good academic qualifications (Honours Degree in Physics or Electrical Engineering) and experience in industrial design Laboratories. There are also openings for graduates trained in these branches, but without industrial experience. Applications giving full particulars of training and experience should be forwarded to: Personnel Department, Murphy Radio Ltd., Welwyn Garden City, Herts. W 2639

MARCONI'S WIRELESS TELEGRAPH Co. Ltd., have vacancies for Junior Engineers to work on VHF Transmitter Development and Multiplex Channelling. Candidates should have a Degree in Physics or Electrical Engineering or equivalent qualifications, or should have had good experience on radio development or research. Experience on VHF or Multiplex Channelling is desirable. Good salaries will be paid, based on qualifications and experience. The Company has a Staff Pension Fund. Apply giving full details quoting ref 822A. to Central Personnnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, London, S.W.1. W 2641

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

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 Specifications. 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 2642

SITUATIONS WANTED

ELECTRONICS ENGINEER, B.Sc.(Hons. Eng.), 27, administrative, drawing office, instrument and electronic development, and design experience, seeks responsible post. Box No. W 1234.

EXPERIENCED development engineer (electronics) seeks active partnership in existing firm or new enterprise. Capital available. Box No. W 1236.

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

MERCURY SWITCHES are made by Hall Drysdale & Co. Ltd., of 58 Commerce Road, Wood Green, London, N.22. Phone BOWes Park 7221-2. W 107

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CLASSIFIED ANNOUNCEMENTS
continued on Page 8

CLASSIFIED ANNOUNCEMENTS (Cont'd.)

HORIZONTAL glass-working Lathe, 12-ft bed. 12-in. centres, complete with three movable beads and also fire carriages. Further particulars, S.T. & C., Ltd., Ilminster, Somerset. W 1240

"ELECTRONIC ENGINEERING," January, 1947-May, 1950 inc., also odd copies "Television," Oct. and Dec., 1934, July, 1935. Offers? G. Short, Fowlmere, Royston, Herts. W 1233

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EDUCATIONAL

THE POLYTECHNIC, 309, Regent Street, W.1. Electrical Engineering Department, Head of Department: W. H. Date, B.Sc.(Eng.), M.I.E.E. A special course of four lectures on Ultrasonics and its Applications in Industry will be given by L. I. Farren, M.B.E., Whit.Schol., M.I.E.E., D.I.C., Member of the Staff of the Research Laboratories of the General Electric Co., Ltd., on Fridays at 6.30 p.m., commencing March 2nd, 1951. Fee for the course, 10s. A syllabus may be obtained on application to the undersigned. J. C. Jones, Director of Education. W 2683

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BEST OFFERS for (or offers invited) Cossor Double Beam Oscillograph. Model 1035. Model 1049 purchased for D.C. tests. Box No. W 2688.

PATENTS

IT IS DESIRED to secure the full commercial development in the United Kingdom of British Patent No. 594,799, which relates to "Telemetering Systems" either by way of the grant of licences or otherwise on terms acceptable to the Patentee. Interested parties desiring copies of the patent specifications should apply to Stevens, Langner, Parry & Rollinson, 5 to 9, Quality Court, Chancery Lane, London, W.C.2. W 2658

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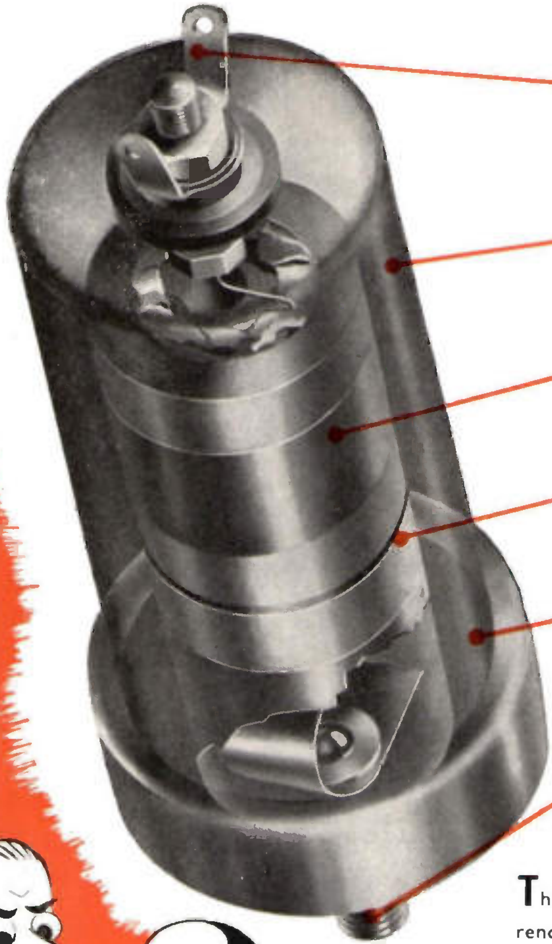

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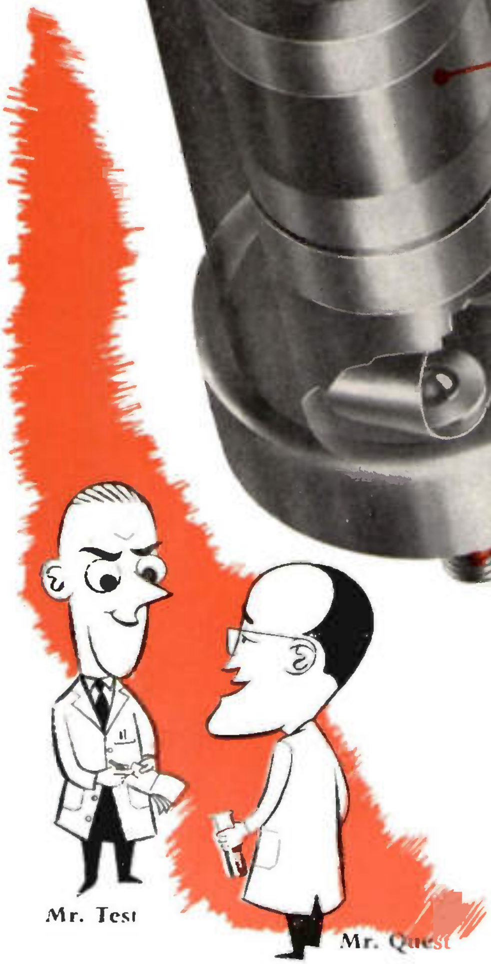

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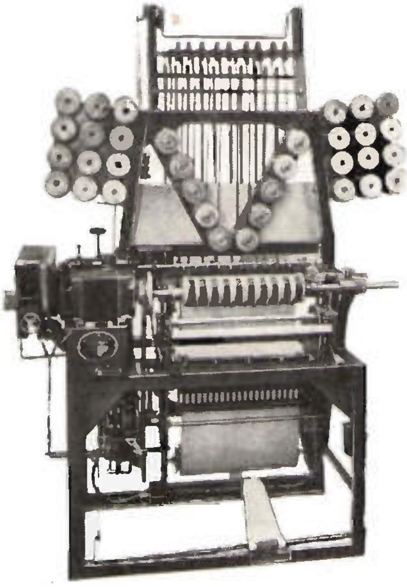

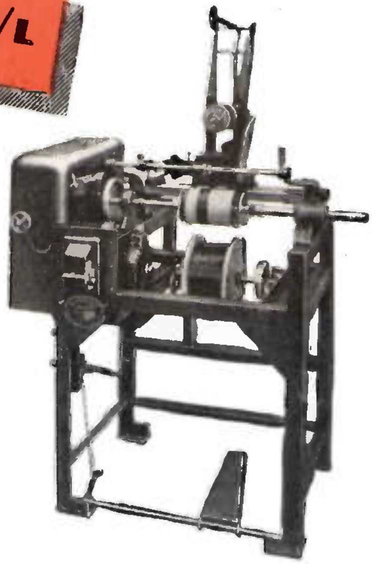

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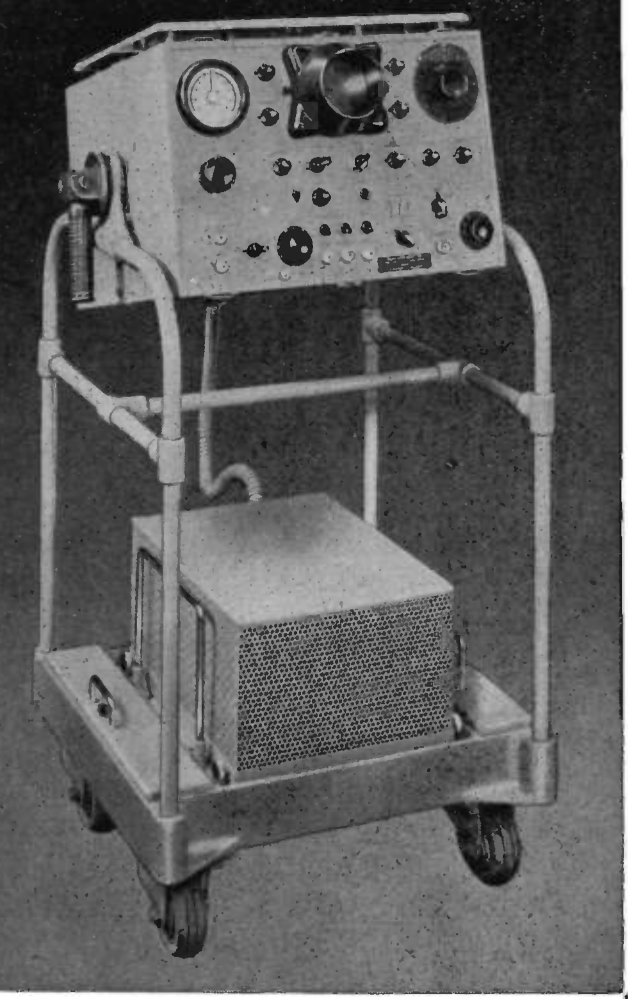

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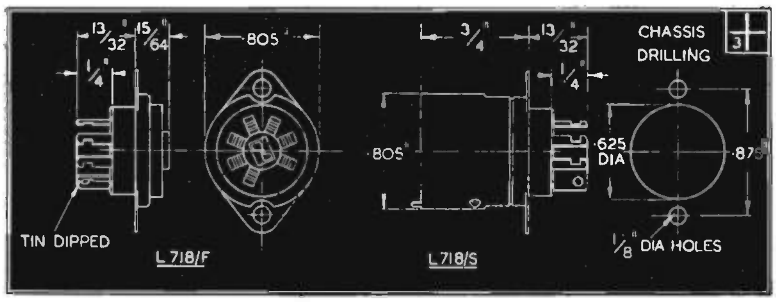

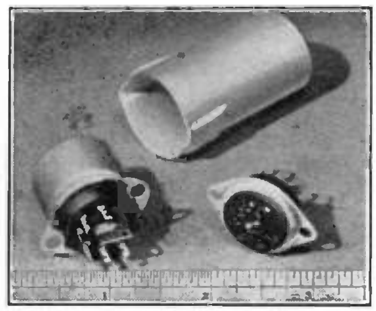

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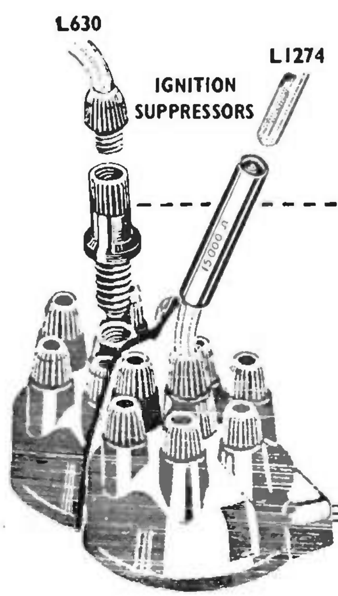

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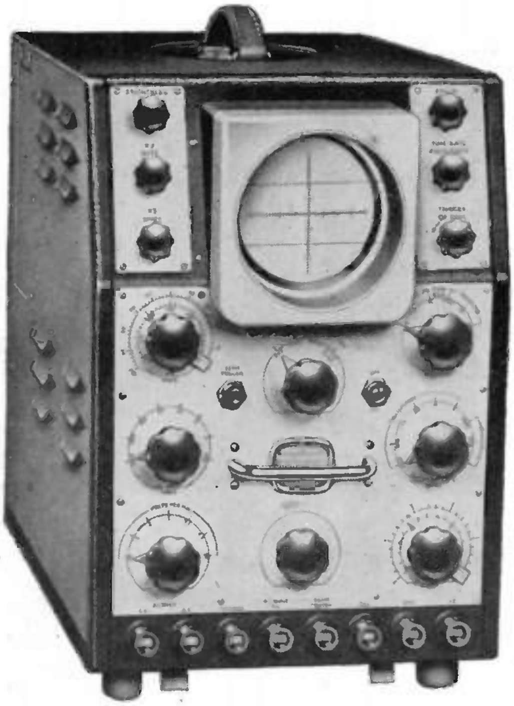

Electronic Engineering

Incorporating
ELECTRONICS, TELEVISION and SHORT WAVE WORLD

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

Vol. XXIII. **FEBRUARY 1951** No. 276

In This Issue

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

Telephone CENTRAL 6565
Telegrams 'LECTRONING, ESTRAND, LONDON'

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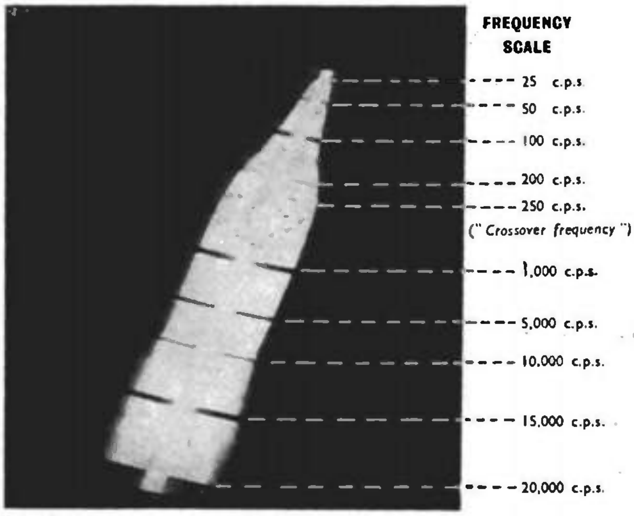

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S.S.22

Electronic Engineering

Vol. XXIII. **FEBRUARY 1951** No. 276.

Commentary

SIR WILLIAM HALEY, Director-General of the B.B.C., at a Press conference on December 15th last confirmed the plans already announced for what might be termed the Five-Year Plan for the expansion of the B.B.C.'s Television service.

Details of the proposals, which include considerable expansion in studio equipment and facilities, are to be found in the Annual Report of the British Broadcasting Corporation 1949-50 (H.M.S.O. 3s.) to which we referred editorially in the November issue of ELECTRONIC ENGINEERING.

According to Sir William Haley, the capital expenditure over the next three years for the development of television will amount to £4,250,000 representing 60 per cent of the Corporation's income, and the timetable for the completion of the new main transmitters will be:—

Holme Moss (35 kW)—North of England Mid' 1951
Kirk o' Shotts (50 kW)—Central Scotland End 1951
Bristol Channel (50 kW)—Wales and West of England Mid' 1952

to be supplemented by five low power transmitters as follows:—

Newcastle	1952
Southampton	1952
Aberdeen	1953
Belfast	1953
Plymouth	1954

This project which was initiated by the opening of Sutton Coldfield in December 1949 is thus expected to be completed by the end of 1954 by which time a coverage of 85 per cent of the total population will be obtained. There will still be some areas, notably East Anglia and the North of Scotland where satisfactory reception is problematical, but even so it is stated that this represents the highest service in the world.

Based on this coverage the number of television licences is expected to grow from the present 600,000 to 1,575,000 by April 1953 and it is anticipated that the radio industry will have no difficulty in keeping pace with the demand for television receivers, provided of course that the re-armament programme does not effect the position.

This rate of growth in the number of television licences appears however to be unduly conservative, and almost pessimistic for it implies that if there are on an average four viewers for every set—which is probably on the high side—then only 6,000,000 or 1/7th of the population living in the service area will be viewers by April 1953. This contrasts very unfavourably with the position of sound broadcasting with its near saturation figure of 12 million licences.

There may be some dissatisfaction over the programme material, and indeed grousing about the television programmes has almost developed into a national pastime, but there can be no complaint regarding the technical achievements in some of the recent outside broadcasts or in the performances from the Lime Grove studios. Moreover, it is well known that the present 405 line system still gives the best possible picture when all the conflicting requirements are taken into account, and requires at the same time a receiver with a minimum number of valves and components.

* * *

SEVENTEEN years have elapsed since the Radio Research Board last published its annual report which was for the period January 1932 to September 1933.

During that period considerable reorganization was taking place which resulted in the amalgamation of the Wireless Division of the National Physical Laboratory and the Radio Research Station at Slough into what is now known as the Radio Division of the National Physical Laboratory with Sir Robert Watson Watt as its first Superintendent.

The Report of the Radio Research Board for the period October 1933 to December 1948 (H.M.S.O. 2s.) which has just appeared after this long interval is therefore very welcome and makes most interesting reading. The Board's Chairman, Col. Sir A. Stanley Angwin in a brief report of some ten pages modestly apologises for not publishing a report since 1933 " for a number of reasons of which the most important were the occurrence of the second World War and the concentration of the efforts of a large section of the staff of the Radio Division on defence projects of very great importance from 1935 onwards," and in a delightful self-effacing manner dismisses the magnificent contributions to the war effort in no more than one page regretting that " there was some deflexion of effort from certain of the long-term projects to those of more immediate practical application."

For the sake of continuity, the Chairman's report contains reviews of the three periods (1) October 1933 to August 1939, (2) September 1939 to August 1945 and (3) September 1945 to December 1948.

In the remaining 50 pages of the Report, Dr. R. L. Smith-Rose, the Director of Radio Research, contributes a more detailed survey of the investigations carried out during the years 1934-47 and concludes with his report for the year ended December 1948.

The present research programme contains 15 major items covering, in the main, the study of the ionosphere and the propagation of radio waves throughout the whole effective radio spectrum.

The Measurement of High Vacuum by Electrical Methods (Part 2)

By F. Wade *

Penning or Philips Ionization Gauge

BY using a discharge tube of special construction in conjunction with a permanent magnet, Penning[20] was able to measure pressures down to 10^{-5} mm Hg. The discharge tube, (Fig. 14) consisted of two flat plates forming a common cathode and interspaced between these plates is a wire loop, this being the anode.

With suitable potentials and no magnetic field the electrons emitted from plates P_1 and P_2 will travel towards the ring R. If a magnetic field of sufficient strength be applied in a direction perpendicular to the plates the electrons will move towards R in a spiral motion about the axis of the magnetic field. The electrons emitted from P_1 will travel in the direction of P_2 where they are repelled and return to the direction of P_1. This process is repeated several times before the electron finally comes to rest, thus the distance travelled by an electron is greatly increased, thereby increasing the probability of ionizing a gas molecule.

The Penning gauge is connected as shown in Fig. 15. For qualitative measurements only, the length of glow in the neon indicator is used; when quantitative measurements are required, the current recorded on the microammeter is expressed as a function of pressure. A typical calibration curve is shown in Fig. 16.

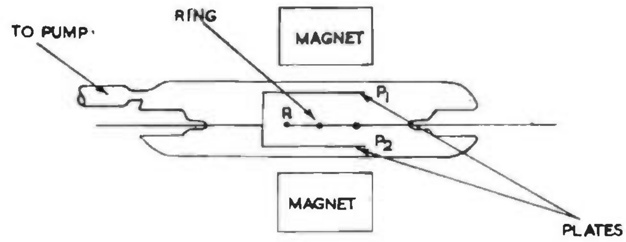


Fig. 14. Philips gauge

Triode Ionization Gauge

The possibility of using a triode thermionic valve as an ionization gauge was first reported by Buckley.[14] Soon afterwards Simon[19] revealed that a triode valve had been used in this manner with considerable success in the laboratories of the "Telefunken Gesellschaft." Since these first reports this type of gauge has become one of the most used high vacuum measuring devices.

In the triode ion gauge the source of the electrons is an incandescent cathode. Ionization takes place in the interelectrode space due to the collision of electrons with gas molecules, the positive ion current being collected by the negative electrode. There are two methods of operating the gauge and they are generally classified as A and B. In method A the grid is made negative to cathode, while the anode is maintained at a high positive potential, thus the grid becomes the collector and the anode is the accelerator. In method B the functions of the electrodes are reversed, i.e., the grid is positive and the anode negative. Method B has been found to be the more sensitive due to the fact that the electrons oscillate about the positive grid with the result that the path taken by the electron is greater than in method A.

A complete mathematical treatment of the ionization gauge has been given by Kaufmann and Serowy.[18] This is for method A only. Their work is based upon an empirical formula of Möller's[35]:

$$p = k\, I_g / I_a \,.\, d \quad \ldots\ldots (14)$$

where p = pressure
k = an empirical constant
I_g = grid current
I_a = anode current
d = distance between grid and anode.

Their investigations had the object of ascertaining the dependence of the magnitude of k on the potentials, both empirically and theoretically. For their experiments they used a valve with the usual concentric electrode arrangement where:

r_0 = radius of filament wire
r_1 = radius of grid
r_2 = radius of anode.

and cathode, grid and anode voltages = V_k; V_g; V_a.

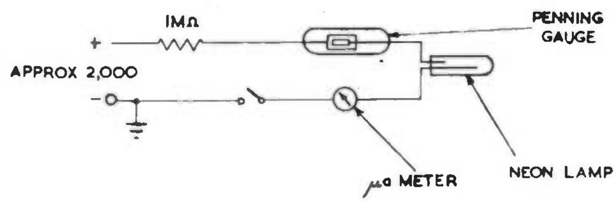


Fig. 15. Philips gauge with indicator

They show mathematically that:

$$I_g / I_a = \frac{p}{b(V_a - V'_g)} \int_{r_1}^{r_2} r f(V)\, dV \quad \ldots\ldots (15)$$

where p = pressure

$$b = \frac{1}{\log_e (r_2 / r_1)}$$

V'_g = an imaginary charged surface of fictitious potential V'_g.* The second term was arrived at under the simple

*In the absence of space charge the action of the grid in a triode can be represented by the action of a conducting "Equivalent plane" in the same position as the mid-plane of the grid. The effective grid voltages in this plane are:

$$V'_g = \frac{V_g - DV_a}{D\left[\frac{1}{\log_e}(r_1/r_0) + \frac{1}{\log_e}(r_2/r_1)\right] + \frac{1}{\log_e}(r_2/r_1)} \quad \ldots (17)$$

where $D = 1/\mu$;
μ = amplification factor

For a more complete treatment of this subject the reader should consult the works of Dow,[36] Chaffee[37], Liebmann[38], or any reference book on radio valve design.

* *Atomic Energy Research Establishment, Harwell.*

assumption that if the initial velocity of the electrons is zero and is therefore only affected by V, therefore the number of ions N, per unit path traversed will depend upon this value and on the density of the gas molecules and will thus be directly proportional to p.

Thus:

$$N = p\,f(V) \quad \text{.................. (16)}$$

Kaufman and Serowy state that as V^1_g can be replaced by known terms, it is possible to calculate the gas pressure for valves of known goemetry.

The theoretical treatment of the use of the ionization gauge in method B is far from complete. It is of a much more complex nature than when the gauge is operated as method A. This is mainly due to the fact that it is difficult to estimate the number of times that the electron oscillates about the grid.

In method B the anode of the valve becomes the collector and the grid by virtue of a high positive potential becomes the accelerator. In this mode of operation electrons will leave the filament and travel towards the grid. Owing to their high velocity and the open mesh of the grid, the majority will pass through and will continue moving towards the anode. At some point between the grid and anode they will reverse direction and travel back towards the grid. The majority will pass through the grid mesh and will travel towards the filament until they change direction and begin the whole cycle again.

Reynolds[39] has investigated this problem and has shown that it is possible to calculate the average number of journeys made by an electron. For his investigations he

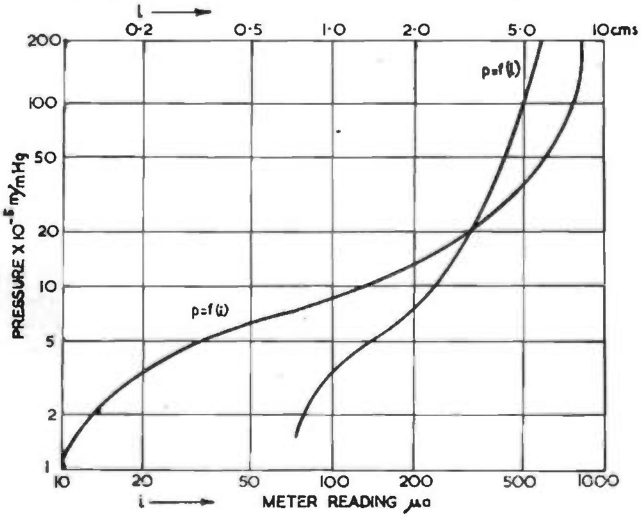


Fig. 16. Calibration curve for Philips ionization gauge

used an ionization gauge developed by Dushman and Found.[17]

Fig. 17 shows the potential geometry relations for this gauge. Neglecting space charge it shows diagrammatically the distance that an electron travels and also the fields acting upon it. In the case taken, the electrodes are concentric cylinders and it is assumed that the radial fields are linear. The velocity of the electron at A^1 is determined by the value of the positive potential applied to the accelerator V_a. If now V_i is the ionizing potential of the gas or gases under investigation, then between the points A^1 and B^1 the electron will have sufficient energy to ionize a gas molecule. The point of reversal of the electron in the grid anode space is at D. Neglecting the space charge of the filament the electron will travel back again along the same path. There is, of course, the likelihood of the electron being collected at A^1, or it may continue to oscillate about the grid until it is finally collected. Therefore, the distance that the electron travels in which ionization can take place is some multiple of $2 \times A^1B^1$. It has previously been shown in Fig. 7 that the probability of ionization will vary with the voltage applied to the accelerator as well as the gas under investigation. From this curve it is thus possible to approximate the probability of an electron producing a positive ion in one single journey between A^1B^1. This is done by integrating under the curve of Fig. 7 between the two defined limits V_a and V_i and then multiplying the result by the distance A^1B^1. The probability when multiplied by the value of the electron emission current I_{em} will give a value for I^1_p, this being the positive ionization current produced by a gauge at a pressure of 1 mm Hg. This is assuming that the electron traverses the distance A^1B^1 only once.

Reynolds calculates the value of I^1_p by using a formula of Thompson. The average number of times that an electron traverses the grid anode space is given as:

$$Z = \left(\frac{2\theta}{1-\theta^2}\right) I_{em} \quad \text{.............. (18)}$$

where θ = effective open area of grid

I_{em} = electron emission current.

The calculated and measured values of I^1_p did not agree and it was found necessary to introduce a correction factor of 3.9 to bring these results into agreement with each other.

Alphatron Gauge

The most recent of all types of vacuum gauges is the

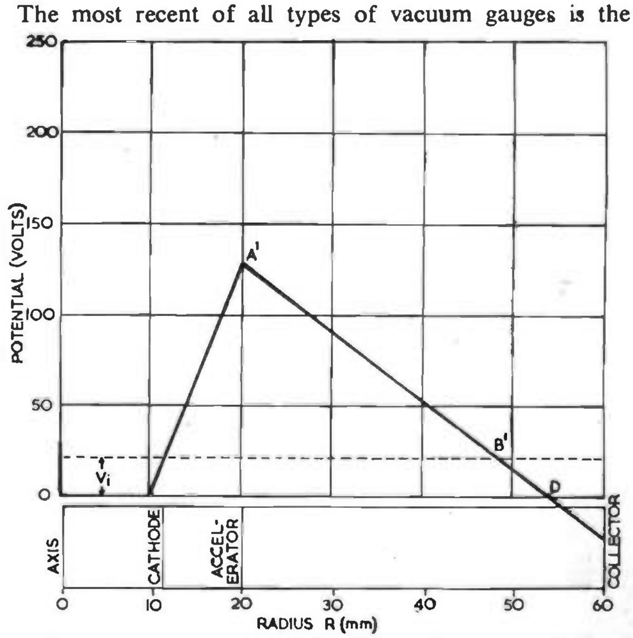


Fig. 17. Potential geometry relationship for Dushman and Found ionization gauge (Reynolds)

Alphatron Ionization Gauge. This gauge contains a small radium source which emits alpha particles. Any gas molecules present in the gauge are ionized, thus the ionization current is a function of the pressure and can be expressed as such. The ion current is very small and it must be amplified on a high gain D.C. amplifier. Meller[21] has described a gauge and amplifier of this type and has given the working range of this gauge as 10^{-4} mm Hg. to 25 mm Hg.

Knudsen Gauge

The only absolute vacuum measuring gauge that has been developed so far, that can be operated electrically, is that of Knudsen.[40] The operation of this gauge is dependent upon the radiometer effect. This is an effect which occurs when a gaseous medium is at such a pressure that the mean free path is much greater than the vessel in which it is enclosed. Under such conditions, two surfaces at different temperatures will exert a mutual mechanical force. Knudsen has shown that if two plates are enclosed in a vessel containing a gas at a pressure p, and that the temperature of the sides of the plates facing each other is T_1 and that of the enclosure T_2, the plates will be repelled by a force F.

Where:

$$F = p/2\ (\sqrt{T_1/T_2} - 1) \text{ dynes per cm}^2 \quad \ldots\ldots (19)$$

The resultant force is thus independent of the type of gas present. Knudsen applied these principles in the mechanical arrangement as shown in Fig. 18.

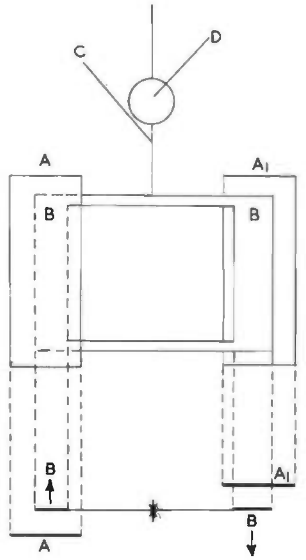


Fig. 18. Mechanical arrangement of a Knudsen gauge

A and A_1 = two fixed plates, electrically heated.
B = cold plate suspended by means of C.
C = quartz fibre to which D is attached.
D = glass mirror.

He found that the formulæ was only valid under the following conditions:

(i) The distance between the plates was small compared with the mean free path.

(ii) The dimensions of the plates are such that the edge effects could be neglected.

He also found that under certain temperature conditions Equation (19) could be re-written thus:

$$p = \frac{4F.\,T_2}{T_1 - T_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (20)$$

By including the physical constants of the gauge, Equation (20) becomes:

$$p = \frac{8\pi^2\sigma d_1}{\text{Dat}^2 d_2} \cdot \frac{T_2}{T_1 - T_2} \quad \ldots\ldots\ldots\ldots\ldots (21)$$

where σ = moment of inertia of moving vane.
a = area of one side of moving vane.
D = mean diameter of moving vane.
t = period of oscillation of moving vane.
d_1 = scale of deflexion.
d_2 = distance of scale from mirror.

The hot plates A and A_1, Fig. 18, were made of platinum foil and were electrically heated. $T_1 - T_2$ can therefore be expressed in terms of ohmic resistance of the hot plate at 0° C, T_1° C and T_2° C.

Then:

$$T_1 - T_2 = \frac{R_1 - R_2}{R_0 a} \quad \ldots\ldots\ldots\ldots\ldots\ldots (22)$$

where R_0; R_1; R_2 are resistances at 0°; T_1°; T_2° and a is the temperature coefficient of the platinum.

On substituting Equation (22) in (21) then:

$$p = \frac{8\pi^2\sigma d_1 a T_2}{\text{Dat}^2 d_2} \cdot \frac{R_0}{R_1 - R_2} \quad \ldots\ldots\ldots (23)$$

Knudsen found that the range of pressure over which his gauge would operate satisfactorily was from 10^{-3} mm Hg. to 10^{-5} mm.

Sherwood[41] was able to improve on this and he made a gauge of the Knudsen type work satisfactorily at a pressure as high as 5×10^{-2} mm Hg.

Much effort has been made to try to produce a Knudsen type gauge of a simple sturdy construction. Among those whose efforts have been directed in this manner are Woodward,[42] Reigger,[43] and Du Mond and Pickles.[44]

Comparison of Various Types of Gauges

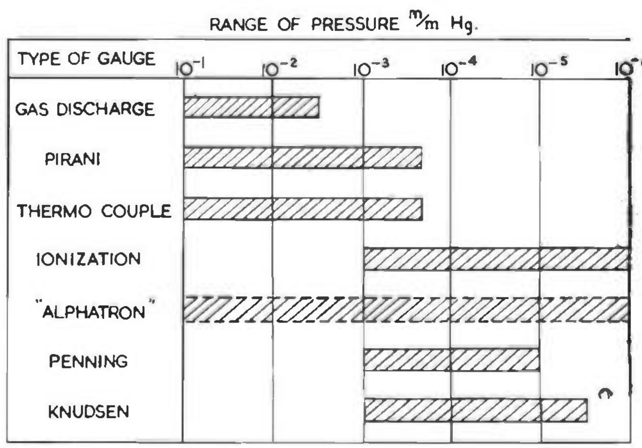
The optimum ranges of the gauges that have been discussed are shown in Fig. 19. It will be seen that with the exception of the "Alphatron" the ranges of pressures covered by each gauge are limited. This makes it necessary to employ two or more gauges to cover the range of pressures associated with medium and high vacuum measurement. The various combinations used will be dealt with later.

With the exception of the gas discharge tube, all the gauges that have been described are still in general use in one form or another. The limitations of the discharge tube are obvious, it can be seen that it would require a highly skilled operator with a very keen sense of colour discrimination to be able to read accurately the pressure by this method. The other methods, i.e., measuring breakdown voltage and length of the Crookes dark space are very cumbersome, thus the discharge tube has gradually been superseded by more scientific methods.

The hot wire gauges are very much used in vacuum work, they require simple electrical circuits and they are reasonably rugged in construction. If by any chance there should be an accident on the vacuum system and a sudden inrush of air takes place, there is no danger of the filament or heater burning out, owing to the low temperature at which these gauges are operated. These gauges are usually calibrated from atmospheric pressure down to the order of 10^{-3} or 10^{-4} mm Hg., so there is not very much risk of the galvanometer being damaged by a sudden increase in pressure.

The disadvantage of the Pirani gauge is that there is a tendency for it to drift from the position of bridge balance. It is obvious that in order to have a means of measuring a vacuum with a constant degree of accuracy, the pos-

Fig. 19. Chart illustrating the optimum ranges of the various electrically operated high vacuum gauges



sibility of drift from the balance position must be made as small as possible. This means that the bridge potential must be constant and that the walls of the glass bulb containing the Pirani gauge must be shielded from draughts and sudden changes of temperature. By immersing the Pirani gauge in liquid air the sensitivity can be increased, it is not normal laboratory practice to do this or to keep the gauge at the temperature of melting ice as sometimes recommended. The practical method of compensating for change of room temperature is that of Hale.[23]

With the thermo-couple gauge the great advantage is that the millivolt meter can be connected direct to the thermo-couple, these readings can then be calibrated and expressed in terms of pressure. Thus the possibility of such things as drift of zero point are eliminated. To obtain greater sensitivity it is possible to use a bridge circuit and include a second thermo-couple gauge in the circuit, as is used in Hale's method of using a Pirani gauge. The current passed through the heater of the thermo-couple must, of course, be kept constant because with a sensitive thermo-couple slight alteration of the condition of the heater will cause a considerable increase or decrease in the thermal E.M.F. It can be seen from Fig. 6 that the range of the thermo-couple gauge is from approximately 10^{-1} to 10^{-4} mm Hg. At the extreme ends of the curve it will be seen that the calibration is very cramped. Under normal conditions the lower limit of the hot wire gauges is of the order of 10^{-3} mm Hg.

The hot wire gauges have a very definite use when used in conjunction with another gauge which will measure the lower pressures. With the majority of these precision low pressure instruments, it would result in damage to the instruments if they were operated at pressures higher than 10^{-3} mm Hg. Thus the hot wire gauge gives an excellent indication when it is safe to switch on the more sensitive instrument.

The three electrode ionization gauge when used in its most sensitive mode of operation, i.e., method B, permits the measurement of these low pressures with comparative ease providing, of course, that the gauge has a good sensitivity.

The greatest advantage of the three electrode ionization gauge is that it can be subjected to the same heat treatment as the valve or tube that is being exhausted. This enables considerably more accurate measurements of the pressure to be recorded. If the gauge is not given the same treatment as the vessel that is being exhausted it may assist in either "cleaning up" the vacuum, thus acting as a getter, or it may reduce the quality of the vacuum when occluded gases are set free. This gauge also enables rapid changes in the pressure to be observed immediately.

It has been found by Blears,[45] that the diameter of the glass tubulation that is used to connect the ionization gauge to the pump system is somewhat critical if it is desired to measure the pressure with accuracy. With a wide bore connecting tube the resistance which is offered to the entry of gases or vapours from the pump system is much less than that of a small connecting tube. This can be seen from the following equation:

$$W = l/r^3 \qquad (24)$$

where W = impedance of connecting tube
l = length of tube.
r = radius of tube.

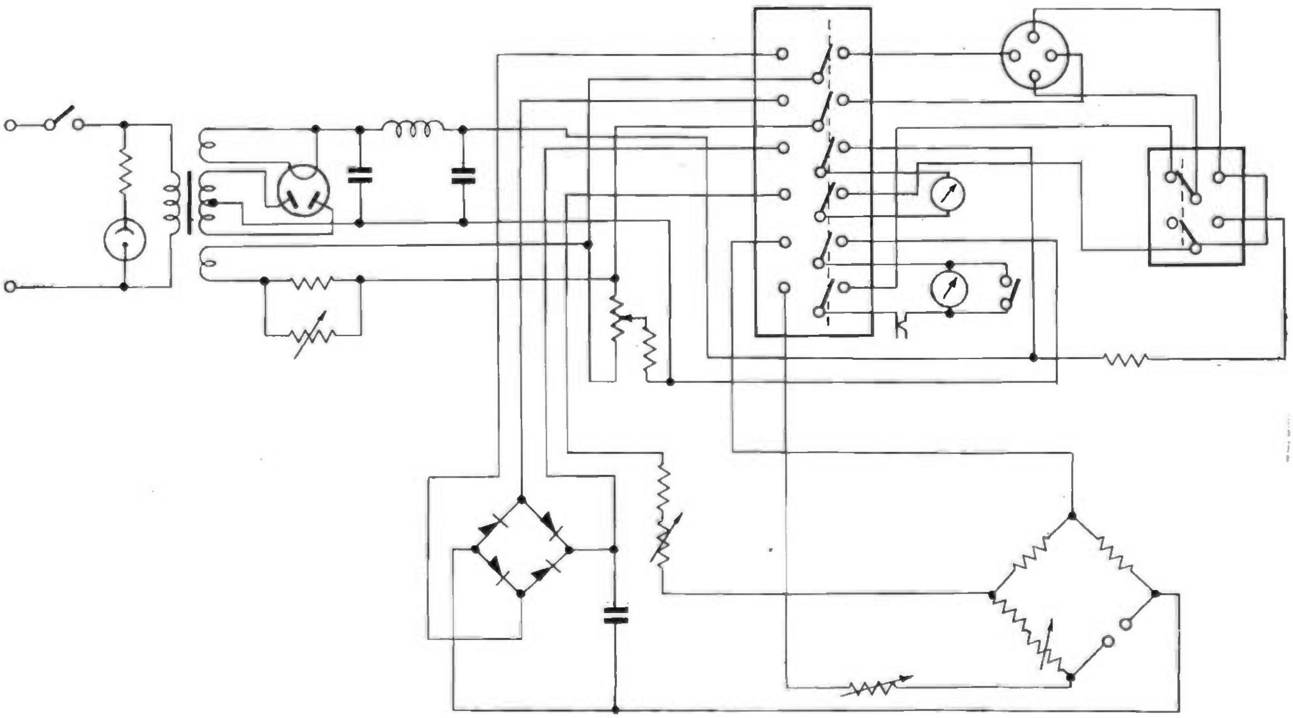


Fig. 20. Circuit of "Cathodeon" combined Pirani and ionization gauge

The Penning or Philips gauge is very suitable for everyday industrial use as it is of a very simple construction and does not require any elaborate precautions to reduce shock or tremor. This gauge has the great advantage that it does not introduce any supplementary vapours of its own; this is due to the fact that while operating there is little or no temperature increase. The choice of the metal from which the cathode is made has some considerable influence upon the sensitivity of the gauge. The first cathodes were made of iron; later it was found that by using a more efficient source of emission such as zirconium or thorium not only was the sensitivity increased but the cathode sputtering that occurs at the higher pressures was reduced. Continual sputtering is detrimental to the life of the gauge, therefore special precautions have to be taken in the mounting of the electrodes, so that the possibility of the formation of leakage paths is reduced. This is usually done by placing glass sleeves over the electrode wires in the glass pinch upon which the gauge is mounted. By using mica disks to screen the lead-in wires small particles of metal may also be deflected away from the vulnerable areas.

The " Alphatron " gauge appears to have several advantages. Firstly, that it will work over a very wide range of pressures, secondly, that it has no hot electrodes and therefore does not cause any supplementary gases to enter the pumping system.

The gauges that have so far been mentioned all suffer from the same disadvantages in that they have to be calibrated against some form of absolute gauge.

The only form of an electrically operated absolute vacuum gauge is the Knudsen. As shown in Equation (23), given certain information, the performance of the Knudsen gauge can be calculated.

The disadvantages of this form of vacuum measurement are many and it is not generally used except for calibration work. The gauge has to be mounted so that it is not subjected to mechanical shock or tremor. The torsion control of the repulsion can give trouble at low pressures; this is due to the relatively large moment of inertia of the suspended system and the virtual absence of damping. If an external means of damping is employed there is a tendency for the zero point to drift. The one great advantage of this form of vacuum gauge is that it does not need different calibration scales for different gases. It also possesses the advantage that the temperature at which it operates is very low, this is particularly suitable for the measurement of pressures on large systems where organic vapours are present.

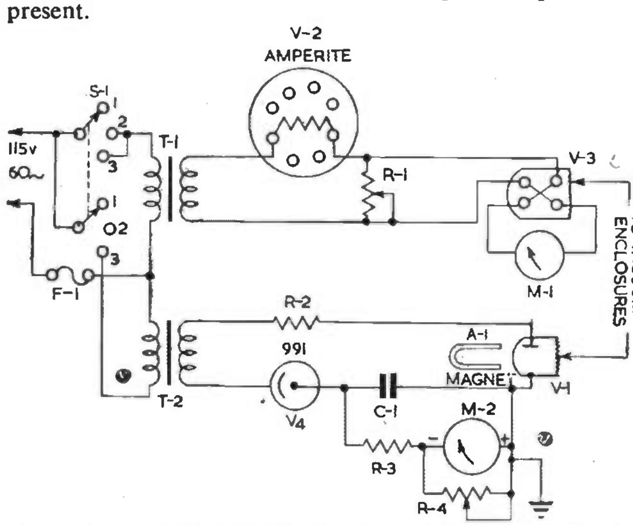


Fig. 21. Combined thermocouple and Penning gauge circuit (Pickard-Smith and Zollard)

It has been shown that no one particular gauge can cover the complete range of pressures that are normally encountered in medium and high vacuum work, i.e., 0.1 mm to 10^{-7} mm Hg., and so it is usual to use two or more gauges to do this. This introduces the undesirable features that more space is taken up by the ancillary electrical apparatus connected with each gauge. This has been overcome in special vacuum measuring equipment.[46] In this invention the same electrical power supplies are used for both the medium and the high vacuum gauge. The medium vacuum gauge may take the form of a Pirani or thermo-couple gauge and the high vacuum measuring device is a three electrode ionization gauge. The electrical circuit is shown in Fig. 20 and from this it can be seen that by the use of a multibank change-over switch, either the medium or high vacuum gauges can be used. With the use of suitable shunts the same meters that indicate bridge current and out of balance current in the Pirani gauge may also indicate the electron current and positive ion current of the ionization gauge.

Provision has been made in this vacuum measuring unit so that the ionization gauge can be bombarded with electrons in order to degas the electrodes while on the pump. It is necessary to do this before any attempt is made to measure the pressure, otherwise a true indication of the vacuum will not be given due to the slow outgassing of the metal electrodes while operating.

Another instrument has been described[47] which consists of a thermo-couple gauge and a Penning ionization gauge. The circuit is shown in Fig. 21. By the use of the two pole three position switches, either the thermo-couple or the Penning gauge can be operated.

Conclusion

The writer hopes that he has shown that the measurement of low pressures is no longer an art but a science that has gradually been evolved from the " hit and miss " methods of the vacuum technicians and workers of the early 18th century. Like many other sciences its implications are not always realized. There is nothing tangible to be seen from the work of the high vacuum engineer unless it is realized that without his efforts to create lower pressures and the means to measure them, there would be no such things as radio telephony, radar, television and hundreds of other devices where thermionic electron tubes are used.

The writer would like to thank the Director of the Atomic Energy Research Establishment for permission to publish this paper, and to Dr. G. Liebmann, of the Research Laboratories, A.E.I., Aldermaston, Berks., for the encouragement given to him in the preparation of a previous paper which has been condensed for the purpose of this article.

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The Home Built F.M. Receiver Reception Tests

By K. R. Sturley, Ph.D., M.I.E.E. *

An experimental V.H.F. *service is now being radiated by the B.B.C. from Wrotham, Kent, with simultaneous* A.M. *and* F.M. *modulation. The 25 kW* F.M. *transmitter is at present operating at 91.4 Mc/s and the 18 kW* A.M. *transmitter at 93.8 Mc/s from Monday to Friday from 11 a.m. to 4.30 p.m. with an hourly interval at mid-day and then from 6 p.m. onwards until the close of the programme being radiated.*

Since the design for the ELECTRONIC ENGINEERING "HOME BUILT F.M. RECEIVER" *(Price 4/6) was first published in September, 1949, a considerable number have been constructed and satisfactory reports on its performance have been received. The Home Built F.M. receiver has a sufficiently wide range to tune to either of the transmitters and constructors may now wish to convert the receiver for reception of* A.M. *signals.*

THE experimental V.H.F. transmissions of F.M. (91.4 Mc/s) and A.M. (93.8 Mc/s) from the B.B.C. station at Wrotham have given the author an opportunity of testing the performance of the home built F.M. receiver under normal conditions and it is thought that the results of the tests will be of interest to experimenters in this field. Modifications which were made to improve the performance of the receiver when operating on the fringe of the service area are also described.

The receiver was tested at two widely separated points, one in Central London and the other at Evesham, about 20 and 110 miles respectively from the transmitter. The field strength over the London area is comparatively high and the test demonstrated little other than that the performance of the set is satisfactory under these conditions, that F.M. gives excellent suppression of impulsive interference and that the use of the wider A.F. band made possible by V.H.F. gives a great improvement in quality. The rendering of the higher frequency musical instruments is realistic and without the harshness and sibilence so often associated with any attempt to achieve a wider frequency response with the average broadcast receiver. The dipole described in Chapter VII was employed, set up in the same room as the receiver. The room, an office, was on a third floor, about 50 feet from a busy road. The main criticism of the receiver was on the score of hum level, which was perceptible during pauses in the programme.

At Evesham the site was favourable to the V.H.F. transmission, being on a hill facing the direction of Wrotham with five miles of comparatively flat country before a rise of 800 feet to the Cotswolds. A folded dipole aerial with reflector and director spaced as indicated in Fig. 50 (page 70) of the booklet was used on a chimney about 40 feet from the ground. A 20 feet coaxial cable connected the aerial to the receiver in a first floor room. A very satisfactory audio output was obtained with some background hiss due to thermal noise in aerial and receiver. The average value of signal at the input to the receiver appeared to be about 100 μV. The hiss, which varied in intensity, was generally only noticeable during breaks in the programme. Monitoring the limiter grid current showed that variations in signal strength occurred quite often but had little effect on aural output because of the high degree of limiting in the receiver. Occasionally, in the trough of a deep fade, noise formed a noticeable background to the programme. An aeroplane in sight of the aerial produced the well known flutter variation in signal and impressed a rhythmic variation on the noise background. A road ran parallel to the direction of Wrotham at a horizontal distance of approximately 40 feet from the aerial. Unsuppressed cars on this produced a faint "spitting" noise in the loudspeaker. The suppression of impulse noise cannot be entirely satisfactory at this signal level because the limiter is not fully effective against noise peak amplitudes comparable with the signal.

The need for correct tuning when signal strength is low was seen, for noise was markedly minimum when the receiver was accurately tuned. The tuning indicator enabled this to be done quite easily and the A.F.C. action held the tuning point satisfactorily.

As a result of the experience gained on these listening tests, an appreciable reduction of hum and microphony

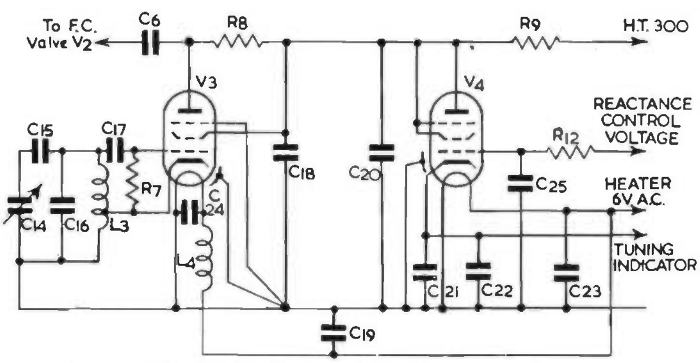

Fig. A. Modifications to the original Fig. 17 to reduce hum level

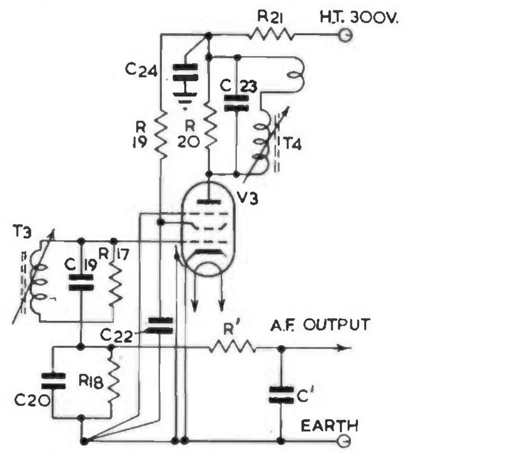

Fig. B. Main alterations to the existing circuit to permit A.M. reception

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and a worthwhile increase in signal-noise ratio at low signal inputs was achieved. The modifications made to the receiver will be considered under the three headings, hum, microphony and noise.

Hum Level

Examination of the hum level of the receiver indicated that it originated in the R.F. unit, and to a less extent in the A.F. unit. Tests on the latter revealed three sources of hum: the mains leads from the mains input plug to the switch *S*1 (Fig, 41, page 59 of the booklet); the H.T. supply to the unit, the hum entering via the anode circuit of *V*1 and grid circuit of *V*2; the first valve *V*1 and its grid circuit.

Hum from the mains leads was suppressed by enclosing them in an earthed screen made from the outer sheath of some aerial coaxial feeder, the insulation and inner conductor of which had been withdrawn. Hum entering from the H.T. supply was reduced to negligible proportions by paralleling *C*10 (Fig. 41) by a 16μF electrolytic capacitor. It was found that hum from the grid circuit of valve *V*1 could be reduced to negligible proportions by surrounding capacitor *C*1 with foil connected to earth and by returning the earth lead of volume control *R*1 to the same earth point as the feedback resistor *R*19 and decoupling capacitors *C*2 and *C*4. Most of the hum remaining after these modifications proved to be due to the magnetic field of the mains transformer *T*2 (Fig. 41) linking valve *V*1. It could be suppressed by surrounding *V*1 by a mu-metal screen.

With the ear close to the loudspeaker slight hiss was observed and this was reduced by increasing the resistors *R*5 and *R*9 from ½ to 1 watt rating. It appeared to be caused by the passage of D.C. through the resistors.

The I.F. amplifier contributed little to hum level, for with the first valve *V*1 (Fig. 26a, page 36) removed, and A.F. volume control set for normal listening, there was little change in output hum by connecting the output lead from the I.F. amplifier. Examination of the R.F. unit indicated that the main source of hum was the heaters of the oscillator valve *V*2 (Fig. 17, page 24). An improvement was registered by inserting R.F. chokes in both heater leads. This effectively places an additional series impedance between cathode and heaters so that any impedance variation between these two electrodes has less chance of frequency modulating the oscillator. For minimum hum a better arrangement was found with the earthed L.T. pin taken to earth separately from all other earth connexions to the oscillator valve *V*3, and with the other L.T. pin connected to it by *C*24(100 pF) and to the 6.3 volt supply through an 8 turn 20 s.w.g. R.F. choke (*L*4) wound on a ¼ in. former. Noise and hum was greatly increased when a finger was brought near the oscillator tuning coil thus emphasizing the need for adequate screening. The variable reactance D.C. valve *V*4 (Fig. 17) also contributed hum due to pick up on the grid lead. This was suppressed by inserting *R*12(0.47 MΩ) in series with the grid lead at *V*4 with a 0.1μF capacitor (*C*25) from grid to earth. A diagram of the component changes made in the oscillator and reactance valve circuits is given in Fig. A. *R*, *L* and *C* numberings are as for Fig 17 (page 24 of booklet). With all these modifications the hum level of the complete receiver was quite low and attention was next turned to a reduction of microphony and to an improvement in signal-to-noise ratio.

Microphony

On page 26 of the booklet the tendency of the EF50 valve to microphony when used as a V.H.F. oscillator is remarked upon. The EF54 valve was considered to be better and the valve pin connexions were changed to accommodate this type of valve. The reduction in microphony was most marked. No change was made in the circuit components or the cathode tap. A.F.C. factor at 1/10 (compared with 1/4 for the EF50) proved to be appreciably better. Attempts to change the cathode tap brought no improvement in sensitivity or signal-to-noise ratio; either the valve failed to oscillate or it squegged. Raising the cathode tap actually reduced A.F.C. action; this was to be expected because it reduces the oscillator current, upon the control of which A.F.C. is dependent.

Signal-to-Noise Ratio

A check on the R.F. amplifier valve *V*1 indicated a gain less than unity. This was raised to about 2 by increasing capacitor *C*5 (Fig. 17) from 5 to 100 pF. Raising the tapping point of the coaxial cable from ½ to 1½ turns of the input coil *L*1 also improved signal-to-noise ratio for input signals of the order of 100 μV. If it is desired to have a balanced input using a twin feeder from the aerial, a 2-turn coil of 26 s.w.g. plastic insulated wire may be inserted between the turns of the input coil *L*1.

On page 48 of the booklet reference is made to the improvement in signal-to-noise ratio obtained by reducing *C*12 (Fig. 26a). Positive feedback appeared to be occurring, but the cause was not known. Investigations eventually showed that it was due to the unit construction. An I.F. feedback loop connecting input and output was formed by connexions from the input end of the I.F. amplifier to the R.F. unit through the Mains Supply Unit back to the output end of the I.F. unit. It was not possible to decouple all the leads from the Mains Unit to the R.F. unit so as to leave only one effective earth, and the next best solution was to bond the I.F., R.F. and Mains Supply Units together at several points by copper strip. This has disadvantages when experimenting so that it was felt better to tolerate the positive feedback and maintain satisfactory signal-to-noise by keeping *C*12 at 5 pF. If bonding between units is carried out effectively, *C*12 can be increased to 50 pF.

Since an appreciable proportion of thermal noise was provided by the frequency changer valve *V*2 of the R.F. unit in the absence of signal, an EF54 was tried in place of the EF50. The improvement in signal-to-noise ratio was not sufficient to warrant making the change.

No further increase in signal-to-noise ratio could be gained by adjustment of the electrode voltages to the valves in the R.F. or I.F. units, though an improvement in A.F.C. action without a reduction of impulse noise suppression could be gained by increasing the H.T. voltage to the final limiter valve *V*4 (Fig. 26b). At the same time there is an increase in A.F. output from the I.F. unit almost in proportion to the increase of the H.T. voltage. The table below gives the A.F.C. correction factor for various H.T. voltages when an EF54 valve is used as the oscillator.

H.T. *V*4	A.F.C. (correction factor)
48	0.11
72	0.075
96	0.05
120	0.04

Thus if the H.T. to *V*4 is 96 volts, a correction factor of 0.05 means that an off-tune frequency of 100 kc/s is reduced to a final mistune of 5 kc/s. This improvement in A.F.C. action is important when signal strength is low because good signal-to-noise ratio is then only obtained when the receiver is correctly tuned.

Reception of A.M. Transmission

Some experimenters may wish to listen to the amplitude modulated V.H.F. transmission at 93.8 Mc/s. Though the receiver has not been designed for A.M. signals it may be modified to accept the Wrotham A.M. broadcast. The grid of *V*3 (Fig. 26b) may be used as the diode detector with *C*20 and *R*18 rearranged as shown in Fig. B and an additional *R*′(0.47 MΩ) and *C*′(50 pF) included as an R.F.

filter in the lead going to the A.F. amplifier. Some form of bias control is needed on $V1$ and $V2$ of the I.F. unit (Fig. 26a) and $V1$ of the R.F. unit (Fig. 17) in order to prevent overloading and obtain good signal-to-noise ratio. This could consist of additional cathode resistors preset to suit the strength of the A.M. signal being received. The EF50 valves used in the receiver have only a limited variable gain action so that some form of input signal control, such as variable coupling between aerial and first tuned circuit $L1$ (Fig. 17), would be essential. A more satisfactory arrangement would be to replace the valves $V1$ and $V2$ in the I.F. unit by EF92 valves, which have variable gain characteristics. Their mutual conductance is, however, much less than that of the EF50 valves. If this change is made automatic gain control could be included by using a Germanium crystal diode from the anode of valve $V2$ (Fig. 26a) with a suitable delay voltage. The ratios of the A.G.C. voltages applied to $V1$ (EF50) of the R.F. unit, and $V1$ and $V2$ (EF92) of the I.F. unit should be about $\frac{1}{4}$ maximum, maximum, and $\frac{1}{4}$ maximum. Suitable decoupling values for R and C in the A.G.C. leads are 0.47 MΩ and 0.1 μF, and the A.G.C. voltage to $V1$ in the R.F. unit could be conveyed through pin 2 of the 7 pin I.F. plug by replacing the Convertor D.C. Volts lead. Pin 2 of the R.F. plug is free and may be used to take the A.G.C. line to the R.F. unit.

A switch may be inserted on the A.F. unit to switch $C1$ (Fig. 41) either to the F.M. or A.M. output so that $R1$ (Fig. 41) is the volume control for both systems of transmission. No changes should be made in $V3$ and $V4$ of the I.F. unit so that A.F.C. is fully operative on A.M. as well as F.M. The sensitivity of the receiver will be much less than for F.M. since the gain of $V3$ (Fig. 26b) is appreciable for small signals and the maximum gain of each EF92 valve is only about 0.4 of that of an EF50 valve. Satisfactory reception should however be obtained within about 30 miles of Wrotham unless the location is particularly unfavourable.

Electric Controllers for Laboratory Furnaces

By M. H. Roberts, B.Sc. *

Two designs of temperature controller for laboratory electric resistance furnaces are described. The general design is based on previous circuits used by Prosser,[1] Coates,[2] and Yates,[3] but more emphasis is laid upon simplicity of construction and operation, economy and use of only standard components, and design for maximum expectation of life and minimum probability of breakdown, the most likely failures being arranged to send the furnace temperature down, not up. The first design gives simple two-position control, and is adequate for general metallurgical heat treatment, while the second design, used in conjunction with a saturable inductor, gives proportional control by smooth variation of power from maximum to nearly zero, and is superior where available voltages, and thermal lag due to furnace arrangement, make the oscillation with two-position control greater than is permissible.

SEVERAL circuits of electronic temperature controllers for laboratory furnaces have been described in the literature, and the reason for presenting two further versions is that they offer greater economy of construction and simplicity of operation, require no special adjustments, and eliminate as far as possible those features which are prone to cause trouble in the form of erratic operation or complete breakdown. High temperature tests lasting several months, such as are common practice now in metallurgical research, make it a matter of considerable economic importance that breakdowns, meaning the loss of much time and work, be reduced to the absolute minimum. The circuit arrangement and choice of components have therefore been directed to this end, and to ensuring that the most likely breakdowns send the temperature down, not up, since a test can frequently be usefully continued after a drop in temperature, whereas a rise in temperature is generally ruinous.

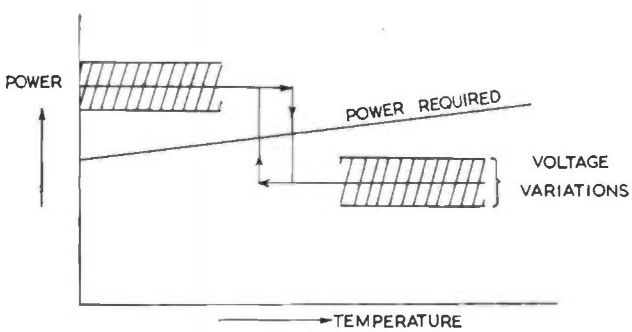


Fig. 1. Operation of two-position controller

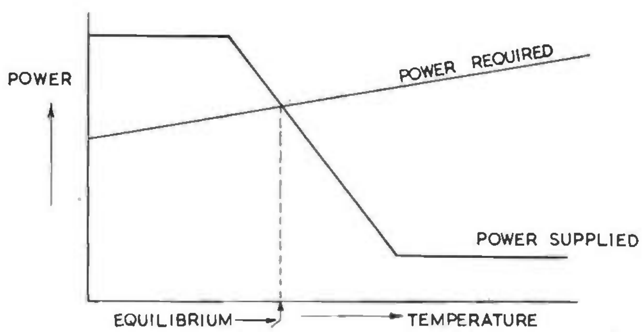
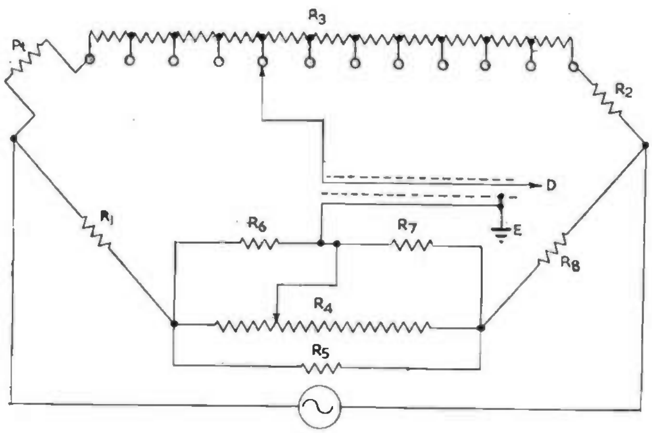


Fig. 2. Operation of proportional controller

* *Brown Firth Research Laboratories*



R1 = 24 Ω, R2 = 32 Ω, R3 = 11 × 1 Ω, R4 = 10 Ω,
R5 = 1.6 Ω, R6 = 1000 Ω, R7 = 1000 Ω, R8 = 24 Ω.
Pt = 11 Ω Resistance Thermometer.

Fig. 3. Arrangement of variable resistors in the resistance thermometer bridge

There is no difficulty in obtaining adequate sensitivity with three valves of modern type, extreme sensitivity being generally unusable because of the lag in heat transfer in the furnace, unless the complication of derivative control is added, and the metallurgist is usually well satisfied with an accuracy of control of ± ½ to 1°C, provided that reliability is first-class. Such controllers are not restricted in application to the maintenance of constant temperatures, but also provide the most satisfactory means of obtaining any desired programme of heating and cooling, by varying the setting of the controller with time.

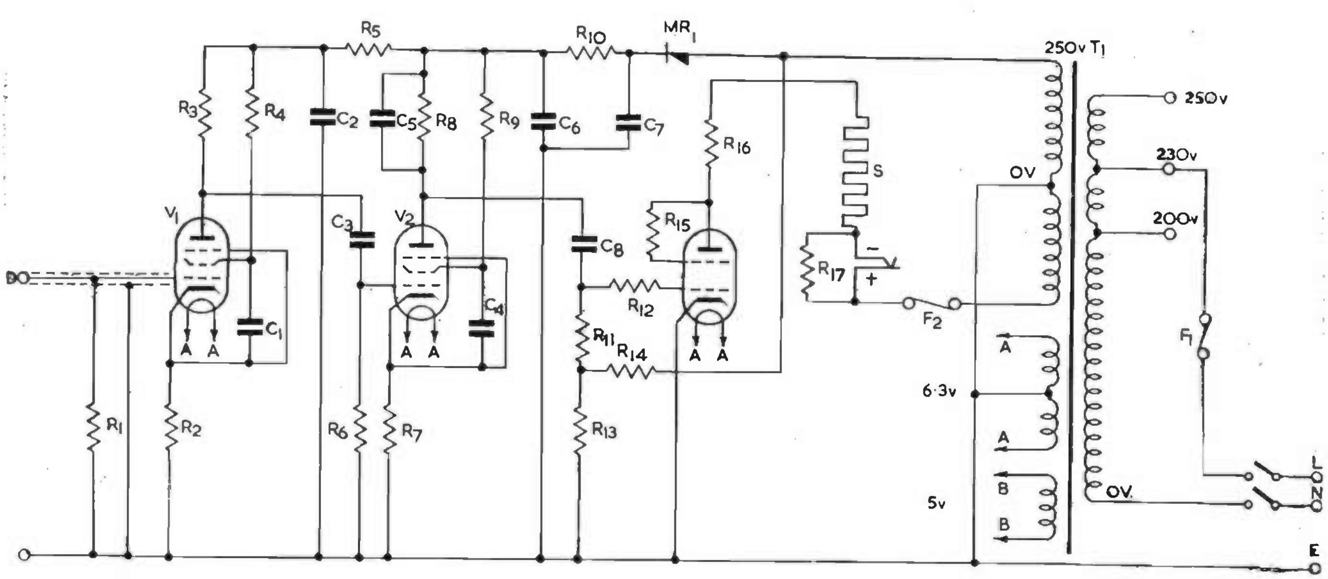
Two general types of controller are useful for such work.

(A) A simple two-position arrangement, the operation of which is illustrated by Fig. 1, switches on to high power when the temperature falls below a certain value, and switches off, or to a reduced power, when it rises above a very slightly higher value. The actual difference in thermometer temperatures at which the relay switches on and off, due to backlash or time lag in the relay, can be made extremely small, by using enough amplification, and does not then limit the accuracy of control. This type is satisfactory where the inevitable hunting or oscillation of temperature is tolerable. The amplitude and period of oscillation increases with the lag in heat transfer from furnace winding to thermometer, so that the usefulness of this type of control depends on the furnace arrangement and the amount of oscillation tolerable. Mains voltage variations necessitate a certain minimum ratio between the average values of low and high power, but the less this can be, the less the temperature oscillates.

(B) A proportional controller varies the power input continuously with temperature as shown in Fig. 2, so that as the temperature rises over a certain range, the power input falls rapidly but smoothly, and the system reaches equilibrium at some point on this curve, where the power input is just what is required to maintain that temperature. This system can be free from oscillation unless the thermal lag and sensitivity are too high. The optimum sensitivity is obtained when the temperature overshoots slightly on reaching the set value, and becomes steady after a few cycles of rapidly damped oscillation. Greater sensitivity will merely produce sustained oscillation. Where the furnace arrangement involves considerable thermal lag, this type of instrument is generally essential to obtain sufficiently close control, as type A would produce excessive hunting.

The most suitable method of "measuring" the temperature is by means of a resistance thermometer, generally of platinum for high temperature work, as the standards of reference can then be passive resistances, whereas a thermocouple requires a standard voltage and cold junction control or compensation. Also a resistance thermometer bridge can be energized by 50 c/s A.C. and the out-of-balance E.M.F. amplified by valve circuits, whereas the D.C.

Fig. 4. Circuit of the Type A controller



R1 = 1 MΩ, R2 = 2.2 kΩ, R3 = 220 kΩ, R4 = 1 MΩ,
R5 = 100 kΩ, R6 = 1 MΩ, R7 = 2.2 kΩ, R8 = 220 kΩ,
R9 = 1 MΩ, R10 = 220 kΩ, R11 = 330 kΩ, R12 = 47 kΩ,
R13 = 47 kΩ, R14 = 1MΩ, R15 = 22 kΩ, R16 = 100 Ω,
R17 = 100 Ω.
V1 = 6J7G, V2 = 6J7G, V3 = KT61 (Osram).

C1 = 0.1 μF, C2 = 0.5 μF, C3 = 0.1 μF, C4 = 0.1 μF,
C5 = .002 μF, C6 = 0.5 μF, C7 = 0.5 μF, C8 = 0.5 μF.
T1 = 250-0-250 V 50 mA, 6.3V 1.5A, 5V 2A,
F1 = 1 amp, F2 = 60mA, MR1 = any 250V, 1mA or more, Metal Rectifier, S = Sunvic H.V.S. Type 602.

signal from a thermocouple circuit would have to be converted by a vibrator or other means to A.C. before valve amplification.

Nothing more complex than the normal Wheatstone bridge is required, but the arrangement of the variable resistances for setting the temperature is a matter of some importance. The arrangement shown in Fig. 3 takes advantage of the very high input impedance of a valve amplifier to make the current through the adjustable contacts almost zero. Actually it is desirable to have a resistance across the bridge output terminals to prevent the amplifier grid from "floating" and picking up stray signals if one of the contacts comes adrift, but it need not be less than 1 MΩ if the grid lead is screened. A step-up transformer between the bridge and the amplifier was found to be not worth while, as it would have to be specially designed to match the bridge, and thoroughly screened from the magnetic field of nearby circuits, while a considerably greater gain was obtained from an extra valve stage, with less trouble and expense. The absence of appreciable current through the contacts means that contact resistance is relatively unimportant and so enables cheap radio-type switches and potentiometers to be used satisfactorily.

The use of a multi-way switch and fixed resistors instead of a potentiometer for the coarse setting *R*3 is preferable as it makes the settings accurately reproducible, whereas a slight displacement on an ordinary small potentiometer as *R*3 would cause a considerable change in temperature. However, for heating or cooling to a desired programme, a helical potentiometer of 10 or 100 revolutions may be used for *R*3, and rotated by a motor. Moderate fluctuations of contact resistance cause no trouble as practically no current passes through the contact. Such a potentiometer is more expensive, however, and is not necessary for steady temperatures.

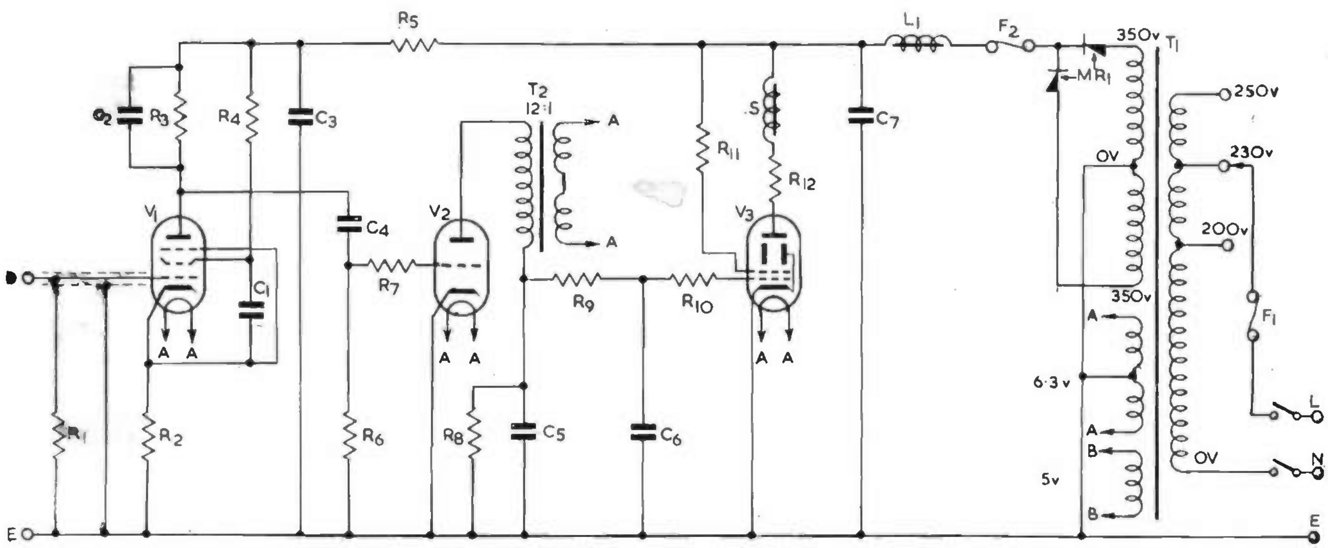
The fine control potentiometer *R*4 can be any easily obtainable value, e.g., 10 ohms, and is made to cover a range equal to one step of *R*3, with some overlap, by using a suitable value of *R*5. *R*6 and *R*7 are nominally 1,000 ohms each, to limit the temperature change produced if the contact on *R*4 fails. On a controller to cover the range 400-1,000° C. (approximately 20·44 ohms on a thermometer of 11 ohms at room temperature), *R*3 consisted of 11 one-ohm resistors, *R*2 32 ohms, *R*1 and *R*8 24 ohms each, *R*5 1.6 ohms. All resistors should be wound reasonably non-inductively, merely for the sake of avoiding magnetic pick-up in loops of wire, and screening is then unnecessary. The entire bridge circuit may conveniently be constructed on a single panel of $\frac{1}{8}$ in. Tufnol sheet, on which the terminal tags are fixed and the resistance wire wound. In the event of a fault, a complete spare bridge unit may then be quickly substituted. No special transformer is needed for the bridge supply, the 5V winding provided for a rectifier valve on a standard mains transformer being quite satisfactory.

Electronic Circuits

In view of the need for the maximum possible reliability and life of the controllers, the designs have been varied somewhat from conventional practices. Metal rectifiers have been used in place of valve rectifiers, and paper capacitors in place of electrolytic, any extra cost or bulk being accepted as necessary. Gas-filled valves have been avoided as they are not always as reliable over extended periods as vacuum types. The use of sharply tuned filters or transformers has been excluded, as such circuits might go out of adjustment or cause errors when the mains frequency varies, as it sometimes does under present conditions. Pre-set adjustments have been eliminated, so that any controller constructed to specification from tested components will work satisfactorily, and the only adjustment required in use is the setting of the bridge circuit to give the desired temperature. A sensitivity control could be incorporated but has not been found necessary. Standard types of transformers and other components have been used, to avoid difficulty or delay in obtaining supplies.

The amplifier circuits are straightforward, but the

Fig. 5. Schematic of the Type B Controller



R1 = 1 MΩ, R2 = 1 kΩ, R3 = 220 kΩ, R4 = 1.5 MΩ, R5 = 100 kΩ, R6 = 1 MΩ, R7 = 220 kΩ, R8 = 47 kΩ, R9 = 47 kΩ, R10 = 10 kΩ, R11 = 6.8 kΩ 2 W, R12 = 47 kΩ 2 W
C1 = 0.1 μF, C2 = 0.005 μF, C3 = 4 μF, C4 = 0.01 μF, C5 = 0.5 μF, C6 = 0.5 μF, C7 = 4 μF.
V1 = SP61 (Mazda), V2 = ECC32 (Mullard), V3 = KT66 (Osram).

T1 = 350-0-350 V 150 mA, 6.3 V 3 A, 5 V 2 A,
T2 = Wharfedale G.P.8
S = Saturable Inductor, Electro Methods Type MAF 20/1150 W.
F1 = 2 amp, F2 = 250 mA, L1 = 20 H, 150 mA,
MR1 = S.T.C. V 25 40 IL.

response is restricted somewhat at higher and lower frequencies than 50 c/s., to make instability easier to avoid.

To distinguish whether the bridge is above or below balance, the triode circuit, as used by Prosser and by Coates, with an A.C. anode voltage in phase with the bridge input, and the amplified bridge output applied to the grid, is simple and satisfactory. No bias voltage need be used, and a high resistance grid stopper prevents the grid from going positive, thus effectively limiting the maximum current, when grid and anode voltages are in phase. When the bridge is the other side of the balance, the grid voltage is in opposite phase to the anode, and the rectified anode current is reduced by an amount proportional to the amplitude of grid voltage. This circuit is much more economical and simpler in operation than the pentode circuit used by Yates, as it does not require a special transformer winding, bias and screen potentiometer adjustments, double diode for limiting, or output transformer. It is used in the type A controller, Fig. 4, as the output stage, since the Sunvic Hot Wire Vacuum Switch used as the power relay responds purely to the heating or R.M.S. value of the current, and half-wave rectified current can be used. The anode supply can then be obtained straight from the transformer, and the D.C. supply of about 1 mA for the previous stages is very economically rectified, and smoothed by *MR*1, *C*7, *R*10, *C*6, *R*5, *C*2. The value of *R*15 is chosen to set the maximum current through the hot wire to a safe value. If a fault in the amplifier caused no signal to appear at the grid of *V*3, the full relay current would be obtained and the furnace would remain switched to full power indefinitely, were it not for the signal introduced by *R*14 and *R*13, which is enough to reduce the relay current below the switching value. Apart from thus displacing the operating characteristic of the controller, this circuit does not in any way affect its operation, but it does confer added safety.

The type A controller, including the bridge circuit, has been constructed, without any crowding or use of miniature components, on a chassis 5½ in. by 11 in. in a metal case 7½ in. high, but with the relay on the outside of the front panel. The retail price of components amounted to about £7, plus £1 10s. for a ready-made chassis and case, and £4 for the relay, totalling £12 10s.

The type B circuit has been designed to control creep testing furnaces, which run continuously for 1,000 to 10,000 hours, so that a breakdown sending the temperature high may mean the loss of months of work. The circuit, shown in Fig. 5, is generally similar to that of Coates, and uses a saturable inductor to control the furnace current. The use of a large tetrode output valve with a D.C. anode supply is in this case the most economical arrangement, giving up to 20 watts input to the saturating winding, so that the magnetic amplification required is not too great. The type MAF 20/1150 W saturable inductor has been designed by Electro Methods, Ltd., to control the 1 kW or so required (at maximum) by the furnace with a nominal 20 W (actually only 15 W is needed) which can be economically provided by the output valve. A smaller valve output would considerably increase the cost of a suitable saturable inductor. *R*11 prevents excessive screen grid dissipation at low anode voltage, but allows a higher sensitivity and less anode dissipation than triode connexion. The variable control grid bias for *V*3 is provided by the rectified and smoothed output of *V*2. A small 12:1 loudspeaker transformer steps up the heater voltage to give about 75 volts A.C. on the anode of *V*2, which is quite adequate for full control of *V*3.

Loss of cathode emission in *V*2 would remove the bias from *V*3 and allow maximum furnace current to flow, so a double triode of ample cathode and anode ratings, with parallel-connected heaters, has been used with the two sections in parallel, to give a greater factor of safety. Possibly this could be improved upon by using a metal rectifier to provide a fixed negative bias for *V*3 and arranging *V*2 to give a positive output, but it would involve additional complication of the circuit. Loss of emission in *V*1 or *V*3, or loss of signal before *V*2, will cause a drop in temperature. It is not practicable to arrange for every possible fault to send the temperature down, but this can be done for the most usual types of fault, such as broken heater, loss of emission, or loss of signal amplification through short or open circuits. Analysis of valve failures in the 18,800-valve ENIAC,[4] during a year of operation, has shown that these are the most frequent faults. All the valves are run well below their maximum dissipation limits, and the H.T. supply, rated at 150 mA, normally supplies only 70 to 80 mA, with 100 to 120 mA during initial heating up of the furnace. The use of metal rectifiers and a choke input filter should ensure the maximum life, and if one rectifier fails to pass current the other should be able to maintain the H.T. supply.

The retail price of components for the type B instrument, including everything but the saturable inductor, is about £13.

The correct operation of both types of controller may be checked by plugging a milliammeter into the anode circuit of the output valve, and connecting a fixed resistance of, say, 30 ohms as thermometer. The change in output current, produced by a resistance of about 10,000 ohms placed across the thermometer, can then be used as a measure of the sensitivity and will show whether the bridge input needs reversing to give the correct sense of operation. The bridge controls should, of course, be set to bring the output current to a suitable point on the operating characteristic, about half maximum. If a meter jack is built permanently into the instrument, the contacts which are opened by pushing the plug in may give trouble, so it is desirable to put a 100 ohm resistance across them, or to use a voltmeter, across the anode load, instead of a milliammeter, to prevent failure of the controller if the contacts become dirty.

The use of a saturable inductor to give continuous variation of furnace current has many advantages. It eliminates the switching relay, a probable source of trouble after long periods of use, and should be as reliable as a transformer. It gives more sensitive control without hunting than a system in which proportioning is done by varying the ratio of on and off periods, since it gives immediate correction for any change in conditions and produces no periodic cycling of heat input. The repeated violent fluctuations of heat input to the furnace and power taken from the supply mains are also eliminated, full power being used only during initial heating up. It is unnecessary to use any variable voltage tappings or rheostats for temperatures in the range 400 to 1,000° C. used for most creep testing. Excellent control has been obtained on furnaces run from a supply subject to large variations of voltage, caused by arc furnaces on the same line, where other controllers of the switching proportioning type have given inferior results.

Both types of controller described have been used for some time in these laboratories by people not conversant with electronic circuits and have given very little trouble over long periods.

Acknowledgment

The author's thanks are due to the Electronics and Creep Laboratories assistants who have helped in constructing the instruments described, and to Dr. C. Sykes, Director of the Brown Firth Research Laboratories for permission to publish this paper.

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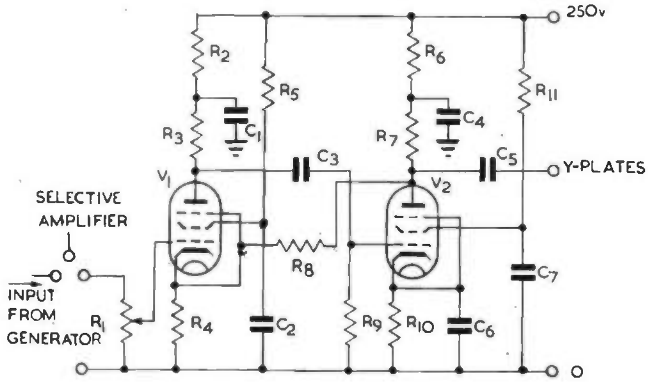
A Precision Electronic Tachometer

By S. W. Punnett, B.Sc.* and H. G. Jerrard, B.Sc., A.Inst.P.*

THE measurement of speeds of revolution of rotating shafts can be carried out in several ways, the method employed depending on the conditions which exist and the accuracy desired. Accurate methods most recently developed appear to be those in which the number of revolutions occurring in an accurately measured interval of time is electronically counted.[1] Whatever the method, however, a tachometer may with advantage possess the following features: it should (1) require little or no alteration to the shaft, (2) impose no load on the shaft, (3) give direct and continuous reading, (4) be capable of the immediate detection and measurement of slight variations in speed, (5) have the speed indicator remote from the shaft, (6) give no ambiguity and be easy to use, (7) be small and light, (8) give high accuracy over a wide range.

Fig. 1. Circuit of A.F. Amplifier

R1 = 2 MΩ, R2 = 20 kΩ, R3 = 100 kΩ, R4 = 1 kΩ, R5 = 300 kΩ, R6 = 20 kΩ, R7 = 100 kΩ, R8 = 2 MΩ, R9 = 0.5 MΩ, R10 = 1 kΩ, R11 = 300 kΩ.
C1 = 4 μF, C2 = 0.5 μF, C3 = 0.01 μF, C4 = 4 μF, C5 = 0.01 μF, C6 = 25 μF, C7 = 0.5μF.
V1 = V2 = 6SJ7.



In this article a description is given of the circuit details of an electronic tachometer accurate to 0.05 per cent which satisfies these requirements and whose upper speed limit can be made far in excess of that likely to be required in practical use.

In the instrument to be described an alternating voltage is generated by the rotating shaft and is fed through an A.F. amplifier to the Y-plates of a cathode-ray tube. The output of a variable frequency oscillator is connected to the X-plates. The resultant trace on the tube is a Lissajous figure. If the frequency of the oscillator be adjusted so that the figure is easily identifiable and if the oscillator frequency be known, then the unknown frequency is immediately found. Any slight variation of speed causes a precession of the Lissajous figure and the change is easily recognizable. Larger changes alter the figure completely and thus there can be no ambiguity.

Description of Components

(a) THE ALTERNATING VOLTAGE GENERATOR.—To generate by the movement of the shaft the required alternating voltage two types of generator unit are employed.[2] The first type is electro-magnetic, in which an alternating voltage is induced in a small pick-up coil placed near the shaft by changing the magnetic flux linked with the coil. The unit is very similar to those employed in tachometers which use an A.C. meter to measure the voltage so produced, and hence give an indication of the speed of the shaft. The second type employs a photo-electric cell which, when placed near the shaft, can receive light intermittently reflected from the shaft. To obtain this reflected light a narrow strip of paper of length equal to the circumference of the shaft and ruled with alternate black and white bands of equal width is attached to the shaft. The paper strip has a matt surface, and in addition the light falling on it is diffuse, so that there is no focus-

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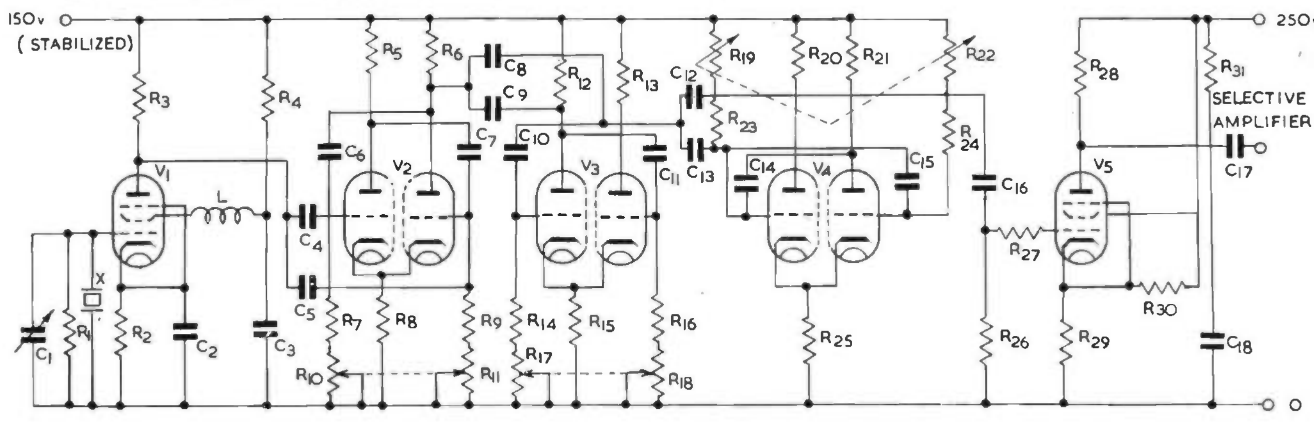
Fig. 2. Circuit Diagram of Signal Generator

R1 = 4.7 MΩ, R2 = 470 Ω, R3 = 100 kΩ, R4 = 22 kΩ, R5 = 22 kΩ, R6 = 22 kΩ, R7 = 22 kΩ, R8 = 150 Ω, R9 = 22 kΩ, R10 = 30 kΩ, R11 = 30kΩ, R12 = 22 kΩ, R13 = 22 kΩ, R14 = 50 kΩ, R15 = 150 Ω, R16 = 50 kΩ, R17 = 30 kΩ, R18 = 30 kΩ, R19 = 100 kΩ, R20 = 22 kΩ, R21 = 22 kΩ, R22 = 100 kΩ, R23 = 300 kΩ, R24 = 200 kΩ, R25 = 150 Ω, R26 = 100 kΩ, R27 = 100 kΩ, R28 = 33 kΩ, R29 = 1 kΩ, R30 = 50 kΩ, R31 = 100 kΩ.

C1 = 12 pF, C2 = 0.1 μF, C3 = 0.1 μF, C4 = 12 pF, C5 = 12 pF, C6 = 0.001 μF, C7 = 0.001 μF, C8 = 12 pF, C9 = 12 pF, C10 = 0.005 μF, C11 = 0.005 μF, C12 = 12 pF, C13 = 12 pF, C14 = 0.05 μF, C15 = 0.05 μF, C16 = 0.001 μF, C17 = 0.01 μF, C18 = 0.1 μF.
V1 = V5 = SP61, V2 = V3 = V4 = 6SN7.
X = 100 kc/s. crystal. L = 15 mH.



ing of the light either before or after reflexion. The light reflected from the strip is allowed to fall on the photo-cell through a narrow slit. Due to the absence of focusing, it is not difficult to see that for the light falling on the sensitive surface of the cell the variation of the illumination from the mean value is approximately sinusoidal in character: thus the voltage generated is also approximately sinusoidal. This arrangement is very flexible and, as no accurate focusing of the light is required, the position of the cell with respect to the shaft is not critical. In many cases there is no need to make special provision for the artificial illumination of the shaft as ordinary daylight will give a satisfactory response.

(b) THE AMPLIFIER AND CATHODE-RAY TUBE.—The output from either generator is applied to a straightforward *R-C* coupled amplifier which has a maximum gain of about 1,000 over the middle range of frequencies. It also gives a reasonable gain over the frequency range 10 c/s to 5,000 c/s and should be sufficient to satisfy all requirements. The circuit diagram and component values are shown in Fig. 1. Careful consideration was given to the

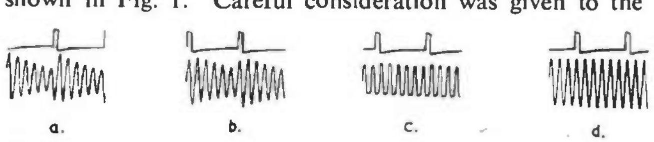


Fig. 3. Output waveforms from (a) first selective amplifier, (b) first selective amplifier after amplification, (c) squaring circuit, (d) calibration unit. The input waveform to the selective amplifier unit appears above each trace. The sixth harmonic is being selected

layout of the amplifier, and screening and de-coupling were employed to avoid, as far as possible, the pick-up of spurious signals, particularly from A.C. power lines. The presence of such undesired signals, however, does not render the tachometer useless or even reduce its accuracy, but merely causes a blurred trace on the screen of the cathode-ray tube. The form of the trace can still be identified and so accurate readings remain possible. The electrical connexions for the cathode-ray tube, which has a diameter of 2½ in. are normal except that for convenience the negative side of its H.T. supply is earthed.

(c) THE CALIBRATION UNIT.—This consists of two sections—one of which is a signal generator to produce a rectangular waveform with a pulse repetition frequency of exactly 100—while the other is a selective amplifier unit[3] with preset tuning to pick out the harmonics from the output of the first section.

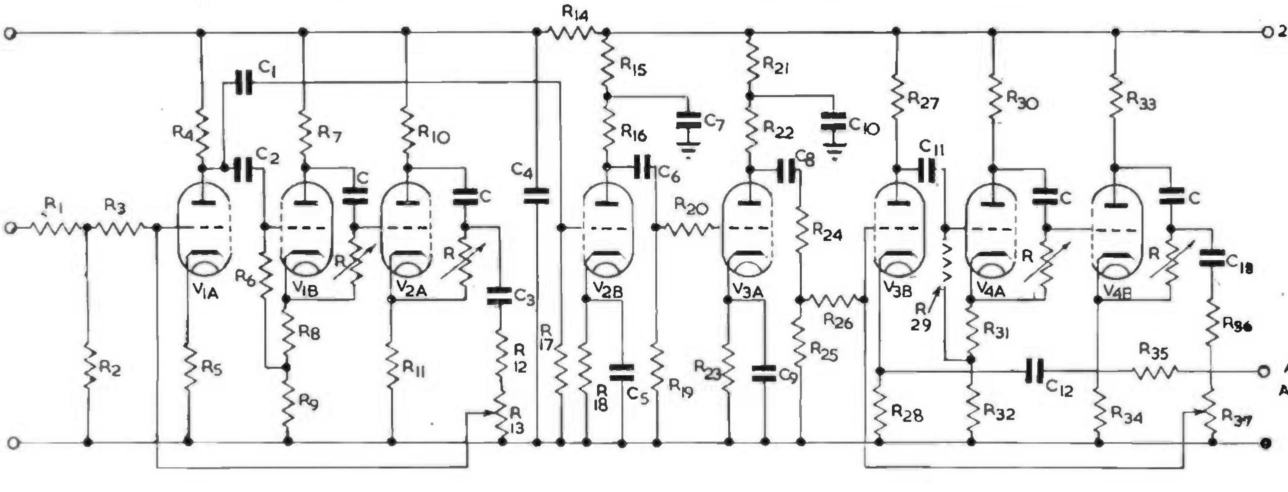
The signal generator consists of a crystal oscillator,[4] three multi-vibrators[5] and a squaring circuit: these are connected in series. The circuit is shown in Fig. 2. The crystal oscillator employs a 100 kc/s quartz crystal which has a very small frequency/temperature coefficient. The output, which consists of short pulses, is taken from the anode of the pentode oscillator valve and is used to lock the three multi-vibrators connected in cascade. Each multi-vibrator produces a 10 to 1 step down in frequency, so that the final output from the last multi-vibrator consists of short pulses with a repetition rate of 100 per second. This output is applied to a squaring circuit as shown in Fig. 2, so that the final output of the unit consists of a rectangular waveform with a mark-space ratio of about 10 to 1. This ratio is not critical; it is merely essential that the output should contain a reasonable percentage of all the harmonics from 1 to 10 of the pulse repetition rate.

As an alternative to multi-vibrators, blocking oscillators, trigger relays of the Eccles-Jordan type or other devices can be used to get the required frequency division.

The rectangular waveform is applied to a selective amplifier unit. Due to the large proportion of harmonics present in this waveform, a single simple selective amplifier is not capable of producing, in the case of the higher harmonics of the pulse repetition rate, an output which is even approaching a sinusoidal voltage. In consequence the unit consists of two simple selective amplifiers which are separated by an amplifying and squaring circuit. The first selective amplifier produces a recurrent damped sinusoidal output (Fig. 3a) whose frequency is an integral multiple of the 100 c/s input. This is amplified (Fig. 3b) and applied to the second squaring circuit whose output (Fig. 3c) then consists of a voltage of rectangular waveform with a mark-space ratio of 1 : 1. This voltage is applied to a second selective amplifier tuned to the same frequency as the first so that it has to handle a signal with a mark-space ratio of 1 : 1 and not, as did the first selective amplifier, a ratio of 10 : 1. Furthermore, it has only to pick out the fundamental of this signal, whereas the first amplifier may be tuned to the 9th or 10th harmonic of its

Fig. 4. Circuit Diagram of Selective Amplifier Unit

R1 = 200 kΩ, R2 = 10 kΩ, R3 = 1 MΩ, R4 = 20 kΩ,
R5 = 1 kΩ, R6 = 1 MΩ, R7 = 5 kΩ, R8 = 1.5 kΩ,
R9 = 3.5 kΩ, R10 = 5 kΩ, R11 = 5 kΩ, R12 = 2 MΩ,
R13 = 1.5 MΩ, R14 = 10 kΩ, R15 = 20 kΩ, R16 = 20 kΩ,
R17 = 0.5 MΩ, R18 = 1 kΩ, R19 = 0.5 kΩ, R20 = 100 kΩ,
R21 = 100 kΩ, R22 = 100 kΩ, R23 = 2 kΩ, R24 = 1 MΩ,
R25 = 10 kΩ, R26 = 1 MΩ, R27 = 20 kΩ, R28 = 1 kΩ,
R29 = 1 MΩ, R30 = 5 kΩ, R31 = 1.5 kΩ, R32 = 3.5 kΩ,
R33 = 5 kΩ, R34 = 5 kΩ, R35 = 2 MΩ, R36 = 2 MΩ,
R37 = 1.5 MΩ. R, variable resistances. (See Fig. 5).
These four resistances are ganged together.
C1 = 0.01 μF, C2 = 1 μF, C3 = 0.1 μF, C4 = 8 μF,
C5 = 50 μF, C6 = 0.01 μF, C7 = 8 μF, C8 = 0.01 μF,
C9 = 50 μF, C10 = 8 μF, C11 = 1 μF, C12 = 0.01 μF,
C13 = 0.1 μF. C = 0.008 μF.
V1 = V2 = V3 = V4 = 6SN7.



input signal. Thus the second selective amplifier, which has a moderate Q-factor, produces an almost sinusoidal output (Fig. 3d).

The circuit and component values are shown in Fig. 4. The two selective amplifiers are identical in form; each consists of a single valve amplifier whose output is applied to two phase shifting circuits connected in cascade. A fraction $1/n$ of the output of the second phase shifting circuit is applied to the input grid of the valve amplifier.

It can be shown that the feedback is given by the expression

$$\beta = \frac{1}{n} \cdot \frac{2 - jy}{2 + jy}$$

$$\text{where } y = \frac{f}{f_0} - \frac{f_0}{f} \text{ and } f_0 = \frac{1}{2\pi CR}$$

This expression is deduced ignoring such effects as stray capacitances, load impedance, etc. The frequency f is that of the applied signal; C and R are the values of the components of the networks connecting anode and cathode of the two phase inverting valves. (See Fig. 4.)

If now the gain of the amplifier valve without feedback is A, then the gain, G, with feedback is given by,

$$G = \frac{A(2 + jy)}{2(1 - A/n) + jy(1 + A/n)}$$

$$= \frac{G_0(1 + jy/2)}{1 + jG_0(1/2A + 1/2n)\ y}$$

where G_0 is the gain when the applied frequency f is equal to f_0. When A is small and n is made very slightly smaller than A so that G_0 is large the following approximate expression is obtained for the gain G,

$$G = \frac{G_0(1 + jy/2)}{1 + jy\,(G_0/A)}$$

so that the effective Q factor of the complete circuit near resonance is approximately G_0/A.

At the frequency f_0 the two phase shifting circuits each produce a phase shift of $\pi/2$, giving a total phase change of π so that positive feedback results and therefore the gain of the amplifier is large. At all other frequencies the feedback is not in phase with the input and this gives a reduced gain. A frequency at which the feedback is positive must always exist with this circuit; tuning is thus very simple. The capacitors, C, employed need not be accurately adjusted. The form of the phase shifting resistors together with their switch arrangement is shown in Fig. 5. To adjust the selective amplifier to the desired frequencies it is only necessary to make small changes in one of the two chains of resistors. In actual practice the phase shift in each phase shifting circuit need not be exactly $\pi/2$; it is only necessary that the sum of the two phase shifts shall be π.

This selective amplifier circuit theoretically has one

Fig. 5. Switch Arrangement of Selective Network

C = 0.008 μF
R1 = 20 kΩ, R2 = 2.22 kΩ, R3 = 2.78 kΩ, R4 = 3.6 kΩ, R5 = 4.7 kΩ, R6 = 6.67 kΩ, R7 = 10 kΩ, R8 = 16.7 kΩ, R9 = 33.33 kΩ, R10 = 100 kΩ.

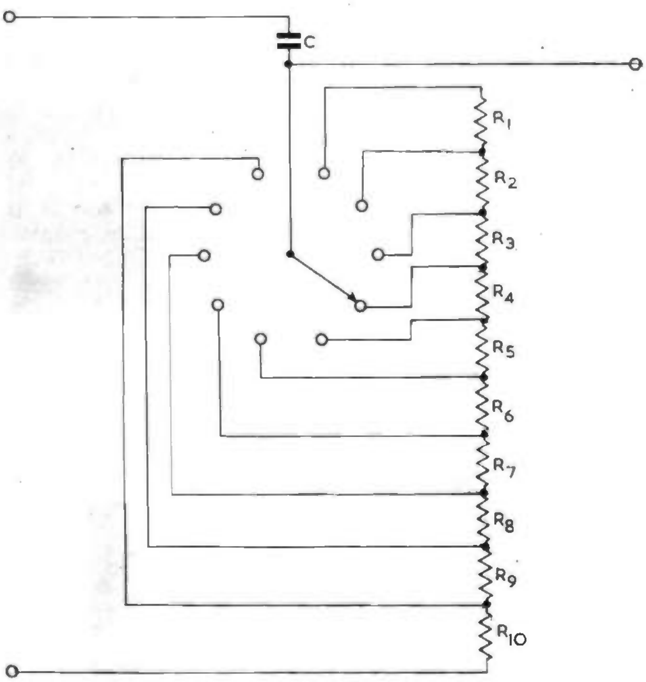
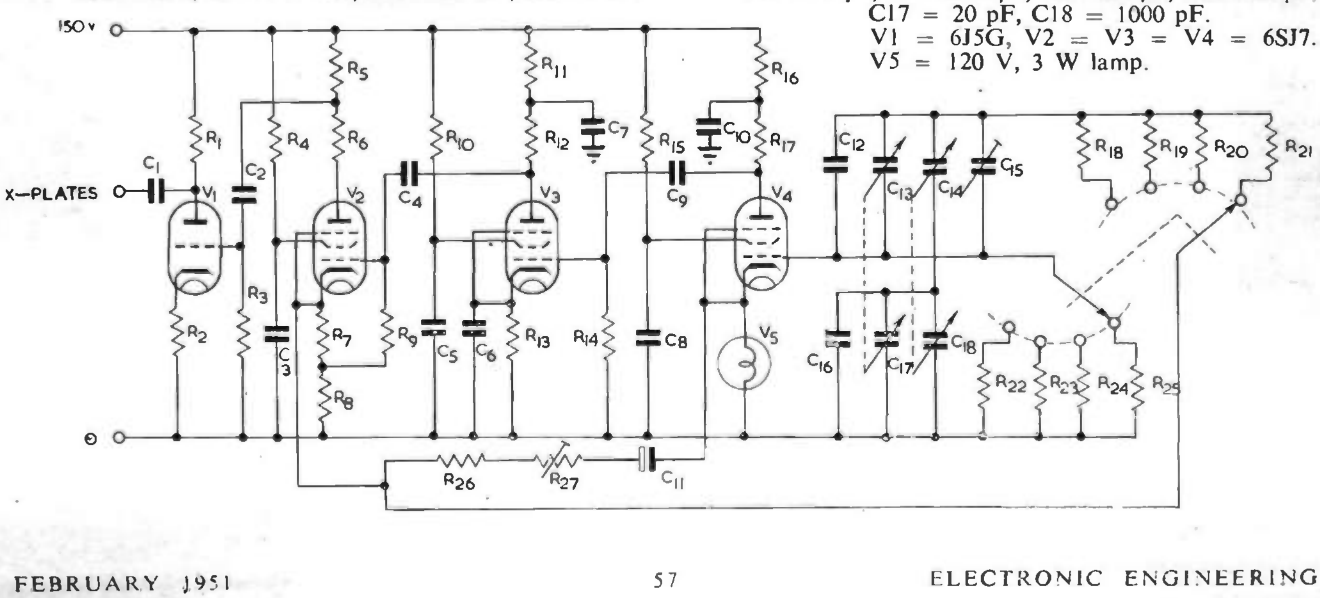


Fig. 6. Circuit Diagram of Variable-Frequency Oscillator

R1 = 30 kΩ, R2 = 1.2 kΩ, R3 = 0.5 MΩ, R4 = 43 kΩ, R5 = 1.8 kΩ, R6 = 15 kΩ, R7 = 1 kΩ, R8 = 10 kΩ, R9 = 2 MΩ, R10 = 43 kΩ, R11 = 10 kΩ, R12 = 2.2 kΩ, R13 = 1.2 kΩ, R14 = 2 MΩ, R15 = 150 kΩ, R16 = 10 kΩ. R17 = 10 kΩ, R18 = 0.22 MΩ, R19 = 0.66 MΩ, R20 = 2 MΩ, R21 = 6 MΩ, R22 = 0.22 MΩ, R23 = 0.66 MΩ, R24 = 2 MΩ, R25 = 6 MΩ, R26 = 3.3 kΩ, R27 = 500 Ω.
C1 = 0.05 μF, C2 = 0.05 μF, C3 = 0.5 μF, C4 = 0.1 μF, C5 = 0.5 μF, C6 = 50 μF, C7 = 8 μF, C8 = 0.5 μF, C9 = 0.1 μF, C10 = 8 μF, C11 = 50 μF, C12 = 600 pF, C13 = 20 pF, C14 = 1000 pF, C15 = 100 pF, C16 = 500 pF, C17 = 20 pF, C18 = 1000 pF.
V1 = 6J5G, V2 = V3 = V4 = 6SJ7.
V5 = 120 V, 3 W lamp.



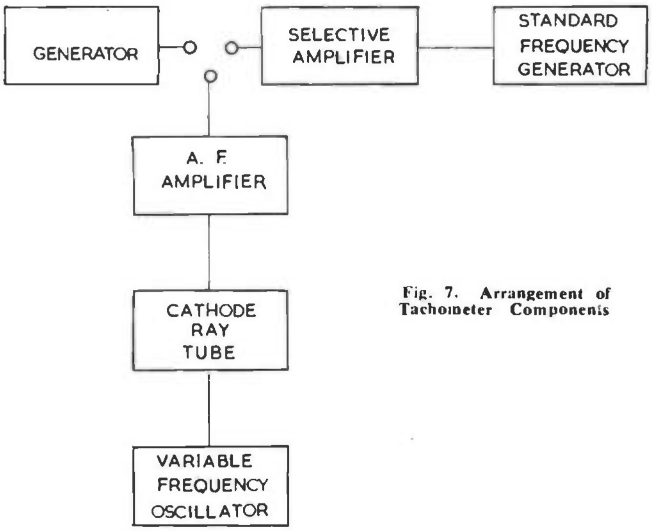


Fig. 7. Arrangement of Tachometer Components

other advantage in that if the effects of stray capacitances, load impedance, etc., are again ignored, the magnitude of the voltage fed back to the input is independent of the sizes of *C* and *R* and of the frequency.

The resultant sinusoidal output of the whole selective amplifier unit whose frequency can be that of any harmonic of the 100 c/s multivibrator is applied to the cathode ray tube after amplification by the main A.F. amplifier (see Fig. 7); this is necessary to produce a reasonable deflexion on the tube. Although in the circuit shown the tenth harmonic is the highest available, it is possible by using Lissajous figures of different orders to standardize a very large number of points on the dial of the variable frequency oscillator. The preset tuning of this tuned selective amplifier unit is accomplished by the use of a four-gang switch which connects the required resistors into the phase shifting networks.

(d) THE VARIABLE FREQUENCY OSCILLATOR. To obtain an accuracy as high as 0.05 per cent it is essential to use a variable frequency oscillator possessing good frequency stability. It is not necessary this should be long term stability since the frequency can be quickly re-checked by the unit described in section (c). The circuit is as shown in Fig. 6.

The principle is the same as that employed in ordinary $R-C$ coupled oscillators but precautions are taken to secure short term stability as far as possible of the frequency of the output. Further it is necessary to open out the scale so that the dial can be read to the desired accuracy. To secure this open scale the frequency covered by each switch position is decreased from the more usual 10 to 1 employed in this type of oscillator to 3 to 1. Capacitance tuning is employed and thus large fixed shunt capacitances are connected across each section of the ganged tuning capacitances so that the ratio of maximum to minimum is 3 to 1. High stability resistors are employed for the resistors *R*18 to *R*25 (Fig. 6) of the frequency determining network. The large values required for these rendered impracticable the use of wire wound types so that

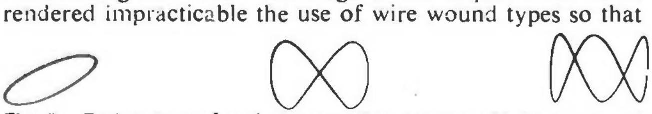


Fig. 8. Typical traces for electro-magnetic generator. First, second and third order Lissajous figures representing speeds of 600, 1,200 and 1,800 r.p.m.

high-stability cracked carbon resistors have been employed. These have a negative temperature coefficient of the order of 200 parts per million per °C and, in conjunction with a suitable selection of capacitors for the fixed shunt across the tuning capacitors, partial compensation for temperature changes has been achieved. Complete compensation with this arrangement is not practicable as capacitors with temperature coefficients greater than plus 140 parts per million per °C are not commercially available. However, after an initial warming up period of about twenty minutes the oscillator gave a highly satisfactory performance at room temperature.

It is possible to obtain an even greater temperature stability by using a frequency determining network in which the capacitances have fixed values and the tuning is accomplished by the use of variable resistors. The increased cost usually does not warrant this especially as the effect of slow changes in temperature is removed by periodic calibration.

The effects of mains voltage variation are eliminated by using a valve stabilizer of standard pattern.[6]

The frequency dial is supplied with a vernier reading to five parts in ten thousand and small ganged trimming capacitors are provided so that the dial may be reset if necessary each time the oscillator is calibrated.

The arrangement of the complete circuit is shown in Fig. 7. Initially the outputs of the variable frequency oscillator and the calibration units are connected to the X and Y plates of the cathode ray tube respectively. By using suitable stationary Lissajous figures the former is calibrated. The calibration unit is switched off, whereupon the tachometer is ready for use with either generator. Fig. 8 shows typical traces.

Conclusion and Acknowledgment

The tachometer described above is suitable for any speed range and possesses the features outlined above in the introduction. The complete unit shown in Fig. 9 occupies

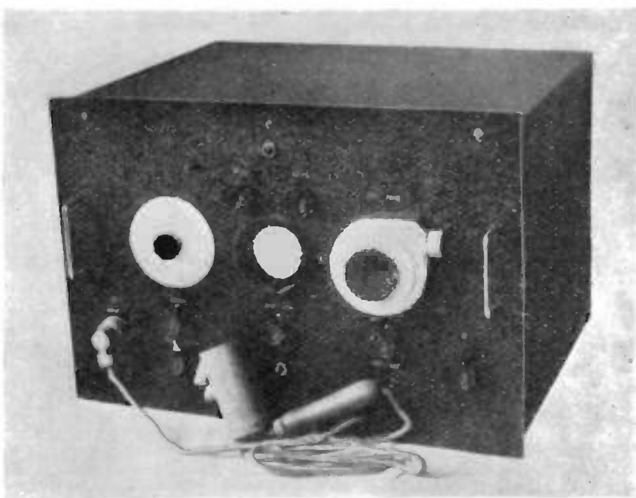


Fig. 9. General view of tachometer and photo-electric generator

a space of only 18 in. by 14 in. by 12 in. and weighs less than 80 lb. If miniaturization technique is employed these figures can be considerably reduced. By the use of a shielded cable from the indicator to the generator head the former can be at any distance from the shaft.

The authors wish to express their thanks to Messrs. R. D. Hilton and G. Q. McColl, who constructed the apparatus, and to Professors A. M. Taylor and E. E. Zepler in whose laboratories this work was carried out.

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Inverse or Reciprocal Scales from Linear Potentiometers

A. F. Boff, B.Sc. *

IN the design of measuring equipment it is often required to divide a potential in accordance with an inverse or reciprocal law. Frequently, wire-wound potentiometers are used in which the core is tapered, or the wire graded, in an endeavour to attain the characteristic required but, owing to the inherent practical difficulties of constructing an element having a truly reciprocal law, the result is very approximate and usually inadequate. In this article a simple method is described by means of which exact reciprocal scales and approximate logarithmic scales, may be obtained using standard linear components.

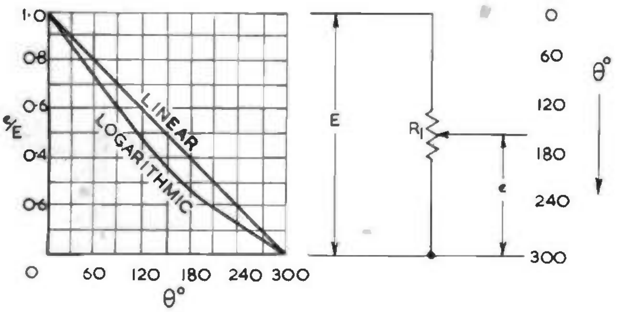


Fig. 1. Characteristics of normal linear potentiometer and logarithmic potentiometer

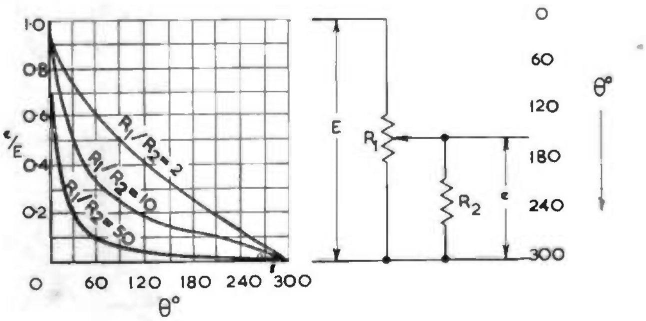


Fig. 2. Effect of shunting a linear potentiometer with a fixed resistor

Fig. 1 shows the characteristic obtained by normal use of a linear potentiometer, and for comparison, the curve of a logarithmic potentiometer of well-known manufacture.

It has been assumed that the total angular rotation of the potentiometer scale is 300°; a figure in accordance with most types commercially available.

Figs. 2 and 3 illustrate the effect of shunting a linear potentiometer by a fixed resistance connected to the moving contact. Values of the ratio $R1/R2$ are indicated on the curves.

In practice the entire range of the curves is rarely required and the useful working range is therefore restricted to perhaps two thirds or less of the available rotation of the potentiometer. A considerable improvement is indicated in Figs. 4 and 5 in which one end of the potentiometer is open-circuited. The method is rendered still more universal by the insertion of a resistance in series with the potentiometer as shown in Figs. 6 and 7, and its effect is illustrated in the accompanying curves.

Design of such a potential divider is influenced by the value of potentiometer $R1$, which is not readily obtainable in wire wound types for values in excess of 100,000 ohms and also by the permissible current from the source of potential.

An example will serve to illustrate application of the device:—

A source of potential of 12 volts is available and a potential divider is required having a range of 10 volts to 1 volt, according to a reciprocal law (Fig. 8). Calculation by the method given below gives the following ratio:—

$$R1/R2 = 10.8 \text{ and } R3/R2 = 0.2$$

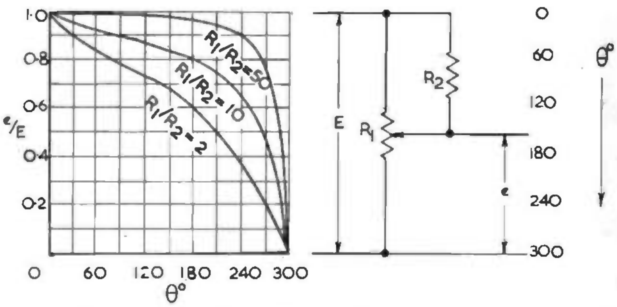
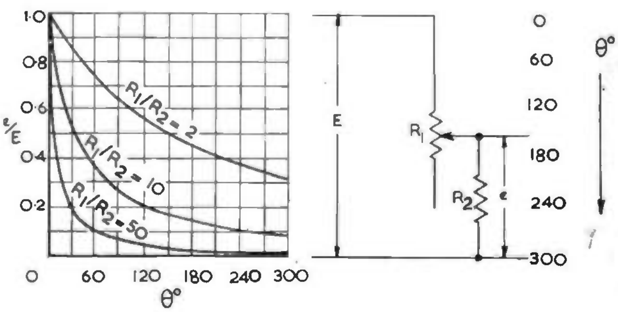


Fig. 3. Effect of alternative method of shunting a linear potentiometer with a fixed resistor

Fig. 4. As for Fig. 2, but with one end of the potentiometer disconnected



In order to keep the current as small as possible $R2$ and hence $R1$ should be as large as possible.

$$\text{Let } R1 = 100{,}000 \text{ ohms,}$$

$$\text{then } R2 = \frac{100{,}000}{10.8} = 9260 \text{ ohms}$$

$$\text{also } R3 = 0.2 \times R2 = 1850 \text{ ohms}$$

The circuit of Fig. 9 will therefore provide the desired characteristic, and the maximum current taken from the source is:

$$E/(R2 + R3) = 1.08 \text{ mA}$$

Calculation. The general mathematical expressions for the curves of Figs. 6 and 7 respectively are,

$$\frac{e}{E} = \frac{1}{A + K\theta/\theta^{\circ}} \qquad \ldots\ldots\ldots\ldots (1)$$

$$\frac{e}{E} = \frac{1}{A + K(1 - \theta/\theta^{\circ})} \qquad \ldots\ldots\ldots\ldots (2)$$

where E = Potential to be divided

e = required portion of potential

* *Formerly of Standard Telecommunication Laboratories, Ltd.*

θ° = range of angular rotation of potentiometer

θ = angular rotation of potentiometer from position of maximum potential

A = constant

K = constant

Consider the circuit of Fig. 6 where $R2$, $R3$ are fixed resistors and $R1$ is a linear potentiometer, then:—

$$\frac{e}{E} = \frac{R2}{R2 + R3 + R1\ \theta/\theta^{\circ}}\left(1 + \frac{R3}{R2}\right) + \frac{R1}{R2}\ \theta/\theta^{\circ}$$

Comparing this equation with equation (1) we see that,

$A = 1 + R3/R2$ .... (3)

$K = R1/R2$ .... (4)

thus by suitable choice of values for $R1$, $R2$, $R3$, any desired values of A and K may be obtained.

Similarly for the circuit of Fig. 7.

$$\frac{e}{E} = \frac{R3 + R1\ (1 - \theta/\theta^{\circ})}{R2 + R3 + R1\ (1 - \theta/\theta^{\circ})}$$

$$= 1 - \frac{1}{(1 + R3/R2) + R1/R2\ (1 - \theta/\theta^{\circ})}$$

Hence by comparison with equation (2)

$A = 1 + R3/R2$

$K = R1/R2$ as before

In the example used for illustration above we have the following data:

$E = 12V$

when $\theta = 0$, e is required to be 10 V

when $\theta = \theta^{\circ}$, e is required to be 1 V

Now using Equation (1) and substituting $E = 12$, $\theta = 0$, $e = 10$ and $E = 12$, $\theta = \theta^{\circ}$, $e = 1$

we have $10/12 = 1/A$ Hence $A = 1.2$

and $1/12 = 1/A + K$ $\therefore A + K = 12$

but $A = 1.2$ $\therefore K = 10.8$

Hence from equations (3) and (4) we have

$R3 = 0.2\ R2$

$R1 = 10.8\ R2$

which are the ratios used in the example.

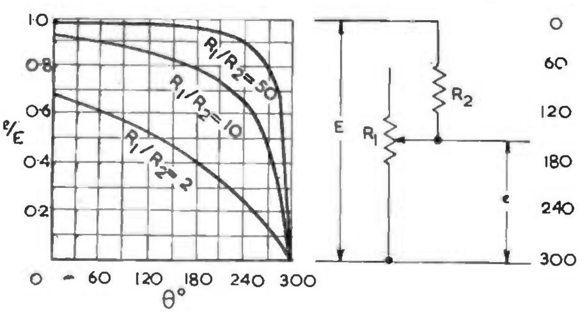
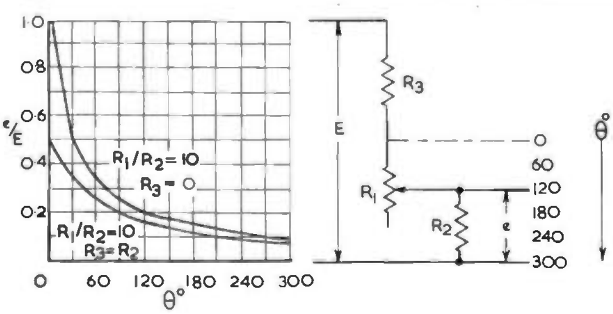


Fig. 5. As for Fig. 3, but with one end of the potentiometer disconnected

Fig. 6. Circuit of Fig. 4 with series resistor added to potentiometer



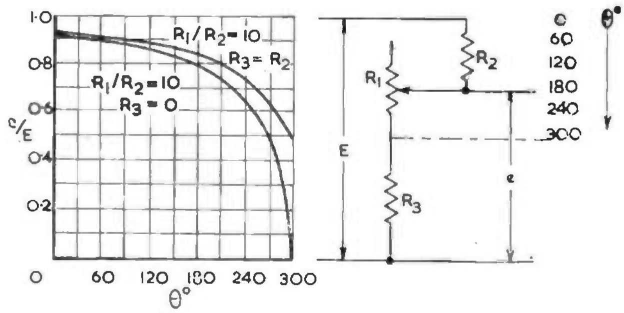
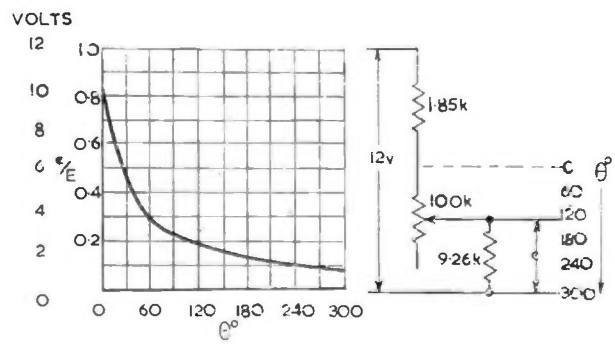


Fig. 7. Circuit of Fig. 5 with series resistor added to potentiometer

Fig. 8. Characteristic required in numerical example

Fig. 9. Required values to give the characteristic of Fig. 8



High-Speed Waveform Monitor

A.E.R.E., Harwell, have developed a high-speed oscilloscope for testing scalers, amplifiers, coincidence circuits, etc.

Y voltage measurements can be made by balancing in a bridge circuit the input signal potential against a D.C. potential supplied by the oscilloscope circuit, and metered by a built-in high grade multi-range moving coil voltmeter. Measurements can be made on A.C. and D.C. signals, and as it is a null method the accuracy is independent of Y amplifier linearity and gain, and of mains input variations.

The Y amplifier enables a sensitivity varying from 2 mm volt to 2.3 cm volt to be achieved with a rise time of 0.07μ seconds. For inspection of hum levels, etc., a sensitivity of up to 15 cm/volt is available with some deterioration of transient response.

Time base speed is variable by means of a switch as follows: 1.5, 5, 15, 50, 150 and 500 micro-seconds, and 1.5, 5, 15 and 50 milliseconds. In addition, by operation of the X gain control the effective length of the trace can be expanded from about 8 to 50 cm, any portion of which can be viewed by operation of the X shift control.

Recovery time varies with sweep speed; it is about 8μS on the 1.5μS setting and 33 mS on the 55 mS settings.

Normally the fly-back is blacked out and a jack is provided to inject external blackout waveforms.

The monitor is manufactured by E.M.I., Ltd., Hayes, Middlesex, and is known as the High Speed Waveform Generator, Type 3794B.

The Effect of Pen-to-Paper Friction in Recording Instruments

By M. J. Tucker, B.Sc. *

THE effect of friction between the pen and chart of recording ammeters and other devices using mechanical registration can be of importance in accurate work. For example, in the recording ammeter used for most of the investigations described in this article (an "Evershed and Vignoles" 500 ohm 3-0-3 milliamp recorder using the Murday system), the maximum deflexion supportable by static friction alone could be over 3 per cent of the scale-width, and a similar figure was obtained when the pen-to-paper friction in an Esterline-Angus 1 milliamp 1,300 ohm recorder was measured. In practice the effect is usually reduced by the movement of the chart, and in many industrial applications where recording meters are used to measure slowly varying quantities that do not produce steep curves, the effect is negligible. However, appreciable errors can be introduced when steep curves are recorded.

The main difficulty in dealing with static friction is its unreliable nature. Measurements of the friction between the same pen and chart roll in a recorder using the Murday System varied from the mean by as much as 60 per cent, though this was mostly due to the pen being tilted at extreme deflexion, in which circumstances the friction also varied according to the direction of measurement. However, even in the centre of the chart successive measurements varied from the mean by up to 20 per cent, the friction being practically independent of the direction of measurement here. This means that calculations of the effect of static friction are approximate and must be used with caution.

Experiment indicates that the stationary and moving friction of the pens is the same, and this will be assumed in this article. It will also be assumed that the friction is the same for all directions of movement of the pen.

The weight of ink in the pen is important and in pens of the reservoir type where this can vary, corrections must be based on a friction value corresponding to the correct weight of ink. A Murday reservoir pen when full of ink has approximately twice the friction of an empty pen.

The effect of static friction may be practically eliminated if there is a comparatively high frequency vibration superimposed on the pen, and it is a well-known practice to superimpose a small amount of 50 c/s current on the input to electrical recorders for this purpose. The A.C. power required is very small, being that which will cause a just noticeable thickening of the record line. Where a vibration is fortuitously present it can invalidate static friction corrections. With seismographs it has been found that vibration from sources such as lorries passing on nearby roads can reduce friction effect to negligible proportions.

This article assumes that the recording is taking place sufficiently slowly for the effects of inertia and of fluid or magnetic damping to be neglected, and that the pen moves perpendicularly to the direction of movement of the paper. The errors involved in applying the results to curved-scale recorders will not be large.

Measurement of the Static Friction

A convenient practical measure of the amount of static friction is the maximum deflexion supportable by static friction alone, and this, measured as a distance, is used below as the static friction constant K. It may be measured directly by letting the pen return slowly from a small deflexion and measuring the final distance from the true zero. The chart must, of course, be stationary during the return, but should be moved forward just before this starts, so that the pen moves over clean paper. When using electrical recorders, the deflecting force is best produced by a small current and the slow return by thick oil in the dash-pot. The average of several readings should be taken. The pen will sometimes catch on a paper fibre, and cases should be disregarded where this has obviously happened.

The value of K can also be obtained from the shape of the error decay curve drawn by the pen when the paper is moving. Fundamentally this method is better as it measures the moving friction and takes an average over a length of line. However, the two methods are found to give similar results and the direct method described above is much less laborious.

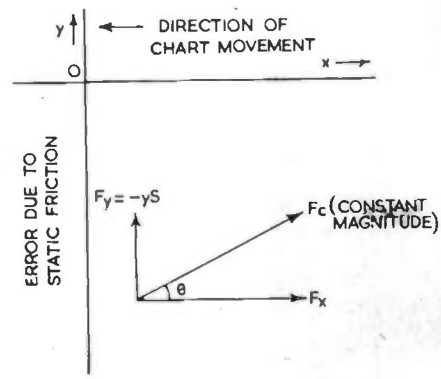


Fig. 1. Diagram of the forces exerted on the pen by its supports

Basic Equation for Calculating the Error at any Point

Fig. 1 is a diagram of the forces exerted on the pen *by its supports*.

y is the error deflexion due to static friction, and hence the force F_y tending to return the pen to the true position is $-yS$, where S is the restoring force per unit deflexion of the pen.

F_x is the force along the direction of movement of the chart.

F_c is the force of constant magnitude necessary to overcome static friction, and is thus the resultant force on the pen when it is moving over the paper. This force will act along the tangent to the curve at the point of writing, so that θ is the angle between the tangent to the curve and the x axis.

Since $F_y = -yS$, the error deflexion y is given by

$$y = -F_y/S = F_c \sin\theta/S$$

K (the maximum deflexion supportable by friction alone) is given by y, so that when $\theta = 90°$

$$K = F_c/S \text{ and } y = K\sin\theta \quad \ldots\ldots\ldots\ (1)$$

* *National Institute of Oceanography.*

This equation is general, and allows the error at any point to be calculated from the slope of the curve. If necessary, corrected curves can be plotted (Fig. 2).

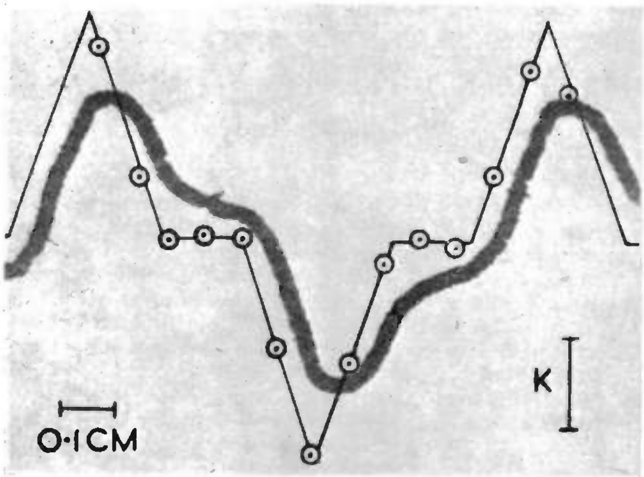


Fig. 2. The effect of static friction

The thin line is the wave-form of the driving current, and the points are calculated from the recorded curve using Equation (1). A small curve was recorded to exaggerate the effect, and has been magnified.

Slowly Varying Records

If the maximum slope of the record is less than about 30°, the effect of static friction is similar to that of viscous or magnetic damping. With these the resisting force and hence the error deflexion produced is proportional to the rate of deflexion, that is to $\tan\theta$, so that for small slopes where $\sin\theta$ and $\tan\theta$ are approximately equal, static friction has a similar effect.

When the slope of the record is 30°, the deflexion due to static friction is $0.5K$.

Step Deflexion and Return to Zero

When a deflecting force is suddenly removed from a pen recorder or a steady force is suddenly applied, static friction will prevent the pen from reaching its correct position immediately. The error deflexion will slowly disappear as the paper moves, and the curve drawn by the pen can be calculated. The shape of this error decay curve is the same for all recorders, only the overall scale is altered by the amount of static friction present.

From Equation (1)

$$y/K = \sin\theta$$

$$\text{Thus } \frac{dy}{dx} = \tan\theta = \frac{\sin\theta}{\sqrt{(1-\sin^2\theta)}} = \frac{y/K}{\sqrt{[1-(y/K)^2]}}$$

This equation can be solved and gives

$$x/K = -\sqrt{[1-(y/K)^2]} + \log_e[K/y + \sqrt{((K/y)^2 - 1)}] \quad \ldots \text{ (2)}$$

It will be seen that this result is in terms of x/K and y/K only, and hence when plotted the resulting curve is universal (Fig. 3). Fig. 4 is an enlarged photograph of an actual error decay curve.

For small values of y/K, (2) tends to the exponential form

$$x/K = -1 + \log_e 2K/y \quad \ldots\ldots\ldots\ldots \text{ (3)}$$

Thus, a plot of $\log_e y$ against x should tend to a straight line with a slope of $-1/K$. As mentioned above, this provides an alternative method of determining K, but is laborious and no more satisfactory than the direct method.

The distance the paper must move for the recorder reading to be correct within given limits can be found from Fig. 3 or Equation (2).

Deflexions of Short Duration

The error in the amplitude of such a record is difficult to assess. If the paper does not move appreciably during the time of deflexion, the error is K, but owing to the steepness of the initial part of the error decay curve the slightest movement of the paper reduces the error considerably. Probably the best procedure is to apply a correction of $0.75K$ in all cases where the pen has dwelt within $0.5K$ of its maximum deflexion for a time corresponding to a chart movement of less than $0.5K$ and this will nearly always give an answer correct within $0.2K$.

Sinusoidal Driving Force

The differential equation obtained for the general case of a sinusoidal driving force is not readily soluble, and so no general result can be given. An approximate solution obtained by Reid[1] and by Nakamura[2] independently also takes account of inertia and viscous damping. If we insert in their formula the conditions that the period being recorded is much longer than the natural period of the recording movement and that the viscous damping is small, it becomes

$$A/A_1 = \sqrt{[1 + (A^1K/A_1)^2]} \quad \ldots\ldots\ldots\ldots \text{ (4)}$$

where

- A is the amplitude of the curve that would have been drawn in the absence of friction.
- A_1 is the amplitude of the curve actually drawn by the pen.
- A^1 is a factor dependent on A_1/L.
- L is the wavelength of the curve.

A^1 is tabulated by Reid and Nakamura. Inserting the values corresponding to curve B in Fig. 5, this gives $A/A_1 = 1.026$, whereas the computed value is 1.05.

To obtain their formula they consider the case of a pen actually drawing a sine wave, in which case the error

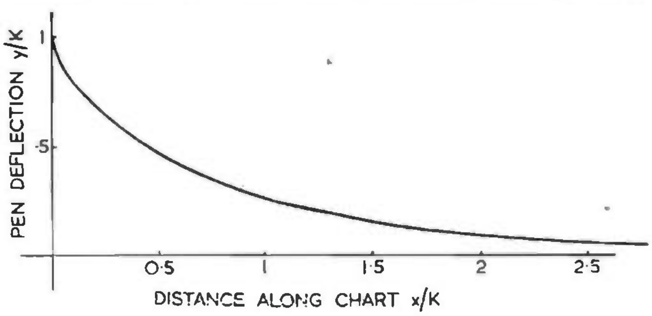


Fig. 3 (above). Universal error decay curve of a recorder kept from its true position by static friction of the pen

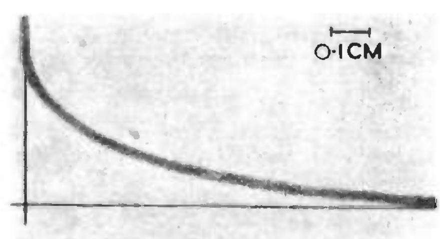


Fig. 4 (right). Actual error decay curve. For this curve a 50 milligram weight was placed on the pen to increase friction

curve may be calculated. This error curve is found to contain harmonics in only small proportion compared with the amplitude of fundamental present, and they therefore neglect these. It so happens, however, that the phases of these harmonics are such that they add up to give a large effect just before the maximum of the curve drawn by the pen. A typical example is shown in Fig. 6. It will be seen that though the amplitude of the third harmonic of the error curve is only approximately 0.2

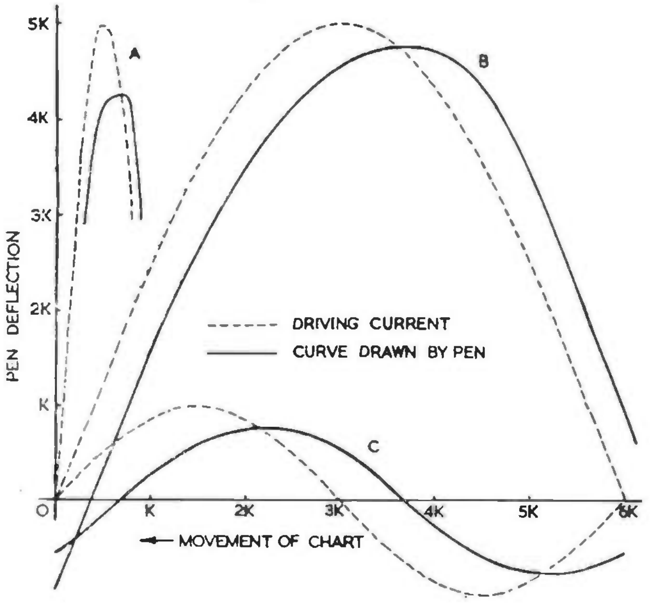


Fig. 5. The effect of static friction on the response of a pen recorder (computed)

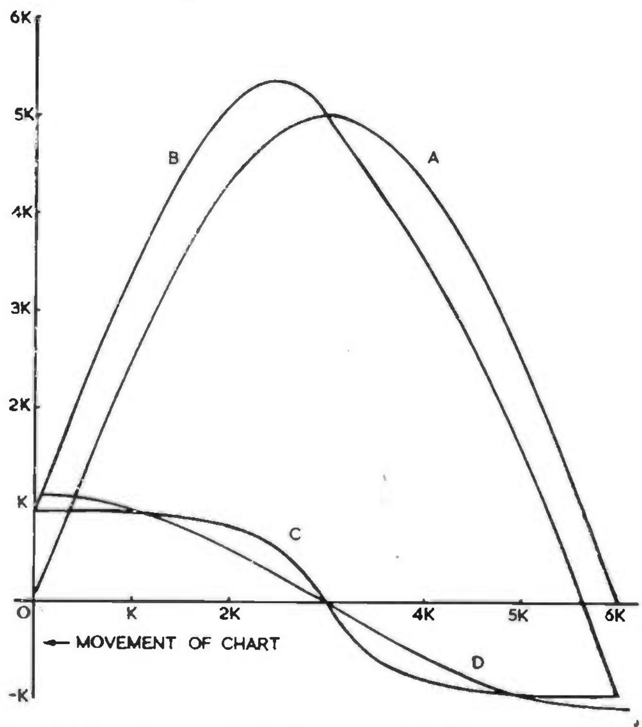


Fig. 6. A is part of a sine curve drawn by a pen with friction
B is the curve that would have been drawn if the pen had no friction
C is the error curve
D is the fundamental content of the error curve

that of the fundamental, and higher harmonics are much smaller than this, they have an effect approximately equal to the fundamental in the last K of horizontal movement before the maximum of the curve drawn by the pen is reached. It is this last K of distance which largely governs the error at the maximum, and hence the ratio of approximately 2:1 between the actual error and that derived from the Reid-Nakamura formula is explained.

The error curve in Fig. 6 is fundamentally a graph of the error *force* due to static friction, and if the system were inertia controlled, as is normally the case in seismographs for which the formula was developed, the third harmonic would have relatively much less effect owing to its higher frequency and could be safely neglected. The Reid-Nakamura formula is therefore only valid in cases where the frequency of the driving force is greater than the natural frequency of the recording device.

It is interesting to note that the A^1 of the formula is the amplitude relative to K of the fundamental component of the error curve.

Individual response curves can be computed by using Equation (1) to develop the curve step-by-step, and Fig. 5 shows three such computed curves.

Sine waves whose ratio of amplitude to wavelength (as drawn by the pen) is less than 0.11 may be treated as "Slowly varying curves" and the formula obtained for the correct amplitude A is

$$A/A_1 = \sqrt{(1+4\pi^2K^2/L^2)}$$
$$\approx \sqrt{(1 + 40\ K^2/L^2)} \quad \ldots\ldots\ldots\ldots (5)$$

This formula will be only slightly in error when applied to considerably steeper waves if the wavelength is long compared with K, as the steep parts of the curve will be remote from the top and any error due to them should have practically disappeared by the time the top is reached. If L is greater than $8K$, curves to which Equation (5) may be applied are those in which

$$A < L/10 \sin(4\pi K/L) \quad \ldots\ldots\ldots\ldots (6)$$

Conclusion

It is well known that the most effective way of eliminating the effect of pen-to-paper friction is to run the paper very fast, but this is not always possible or convenient. Using the information given above it is possible to find how fast the paper must run to reduce the frictional error below a given value, or to estimate the frictional error in a record already taken if the value of K is known.

It is emphasized again that for reasons set out in the introductory remarks, corrections for static friction must be used with a great deal of caution.

The author wishes to thank C. E. Perry, of Messrs. Evershed & Vignoles, for information on the variations of pen-to-paper friction in Murday Recorders.

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Holme Moss Television Transmitting Station

The B.B.C. announce that each of the new Holme Moss television station transmitters has been designed and manufactured by Marconi's Wireless Telegraph Co., Ltd. The vision transmitter is to have a power output of approximately 35 kilowatts, and will employ grid modulation on the output stage. Its valves will be air-cooled, except for the output stage, which will be water cooled. The sound transmitter will be similar to the one at the Sutton Coldfield Station, with a power output of 12 kilowatts.

The area within which reception of the television programme from Holme Moss can be relied upon is expected to be roughly rectangular in shape, stretching from Lancaster to Bridlington in the north, and from Birkenhead to Grimsby in the south. This area has a population of over 11 millions, and includes almost the whole of the West and East Ridings as well as most of Lancashire.

As mentioned on page 489 of the November, 1950, issue of ELECTRONIC ENGINEERING, the vision transmitter will operate on a carrier frequency of 51.75 Mc/s (5.8 metres) and the sound transmitter on 48.25 Mc/s (6.2 metres).

A Choke-Coupled Phase-Invertor of High Accuracy

By R. A. Seymour * and D. G. Tucker†

PHASE-INVERTORS using resistance-loaded triode valves are well-known,[1] and if equal resistances are used in anode and cathode circuits, then the anode and cathode voltages can be almost exactly equal and of opposite phase. It is often possible to make this circuit of adequate voltage-handling capacity, so that grid current can be avoided, but in many applications, e.g., a transformerless rectifier modulator recently described,[2] it is necessary to raise the applied voltage to the limit. In such a case, grid current may flow and, since it flows in the cathode resistor but not in the anode, it unbalances the outputs. This difficulty can be avoided by using a balanced-choke coupling as described below; the grid current may then be permitted to become as large as distortion considerations allow, while still retaining good balance of voltage and accuracy of phase. The same result could not be obtained by the use of an ordinary transformer circuit, since although a transformer phase-invertor may give equal voltages and opposite phases with some accuracy, the phases will not correspond correctly to the phase of the applied signal owing to the large phase-shift introduced by the leakage inductance. This point is of great importance in all feedback circuits, whether they are feedback amplifiers, oscillators, servo loops, etc.

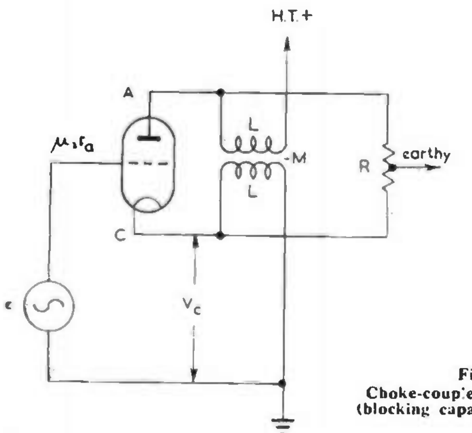

Fig. 1. Choke-coupled phase invertor (blocking capacitors not shown)

The circuit arrangement is shown in Fig. 1 and is analyzed in terms of a general resistance load R which has the requirement that its centre point should remain at earth potential. In the case of a modulator, this corresponds to no carrier leak.

The equivalent circuit is shown in Fig. 2. Here a grid-current circuit is added in which R_G is the effective resistance from grid to cathode when grid current flows. The analysis has two objects, (a) to determine the voltage and phase-shift of the output (V_C) relative to the applied input voltage (e), and (b) to show that grid current does not seriously unbalance the output, although it does do so in the simple resistance-coupled phase-invertor.

(a) Voltage and Phase-shift of Circuit

Since the effect of grid current on the efficiency of the circuit must be small, it is adequate here to ignore the grid current circuit altogether.

Then, since no current flows in $-M$, the point J must be at earth potential.

So $V_{AC} = 2V_C$ (where V_{AC} = voltage from anode to cathode). Thus we have:

$$\frac{-2V_C}{-\mu(e - V_C)} = \frac{j2R\omega(L+M)}{R + j2\omega(L+M)} \Big/ \left[r_a + \frac{j2R\omega(L+M)}{R + j2\omega(L+M)} \right]$$

Now put $2\omega(L + M) = X$ and solve for V_C.

Then
$$V_C = \frac{\mu RX}{(\mu + 2)RX + 2r_aX + j2r_aR} \cdot e \quad \ldots\ldots (1)$$

so that the phase-shift between input (e) and output (V_C) is given by

$$\tan\phi = \frac{2r_a}{(\mu + 2)R + 2r_a} \cdot R/X \text{ exactly} \quad \ldots (2)$$

and if we assume $X \gg R$, the voltage gain is

$$V_C/e \approx \frac{\mu R}{(\mu + 2)R + 2r_a} \quad \ldots\ldots\ldots\ldots (3)$$

From these equations we can see that the phase-shift (which is required to be small) is determined, as far as the choke is concerned, entirely by its shunt inductance, and the leakage inductance has no influence except for the very second-order effect that $L + M$ will be slightly less than $2L$. In a transformer coupling, as discussed earlier, the leakage inductance may have a first-order effect on the phase-shift. Any self-capacitance or other stray capacitance may be included in the term X in Equation (2). It is clear that the anode-to-cathode coupling, which produces negative voltage-feedback, gives the effect of a low internal resistance in the valve, since the greater the amplification factor (μ) the smaller the phase-shift becomes.

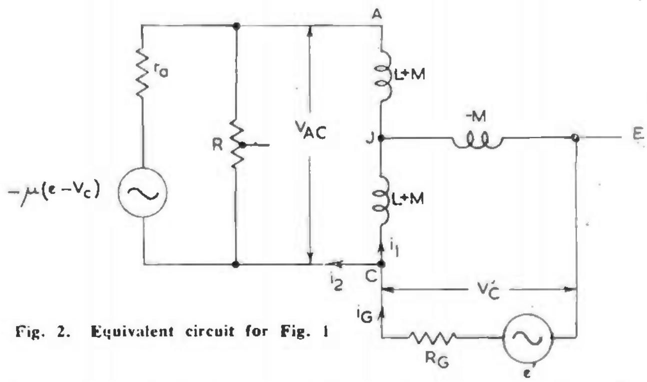

Fig. 2. Equivalent circuit for Fig. 1

Since the equivalent circuit is, in the absence of grid current, quite symmetrical about the point J, it is evident that the voltage from anode to earth is in exact phase opposition to that from cathode to earth.

(b) Effect of Grid Current

It can be seen almost by inspection of Fig. 1 that grid current flowing from cathode to earth will not unbalance the output if the coupling between windings is perfect, and thus the mid-point of the load R will remain at earth potential. It is perhaps more difficult to see this from the equivalent circuit of Fig. 2, but the analysis is quite simple. Ignoring r_a (which can be considered as absorbed into R), the grid current flows into two paths at C. Consider a current i_1 flowing through $L + M$ and $-M$ to earth, and a current i_2 through R, $L + M$ and $-M$. Then by equating voltages from C to J, we have

$$i_1 = \frac{R + j\omega(L + M)}{j\omega(L + M)} \, i_2$$

* Post Office Research Station.
† Royal Naval Scientific Service, formerly Post Office Research Station.

and if V_C' is the voltage from cathode to earth due to grid current, then

$$V_C' = i_2 [R + j\omega(L + M)] - (i_1 + i_2)j\omega M$$

$$= i_2 \left[R + j\omega L - \frac{M}{L + M} \left\{ R + j\omega(L + M) \right\} \right] \quad (4)$$

Now if the coupling is perfect, $M = L$, and then

$$i_2 = V_C'/R/2 \quad \ldots\ldots\ldots\ldots (5)$$

which means that the centre-point of R is at earth potential.

When the coupling is not perfect, i_2 is given by Equation (4) and the out-of-balance voltage at the centre-point of R is given by:

$$V_C' - i_2 R/2$$

$$= i_2 (L - M) \left[\frac{R}{2(L + M)} + j\omega \right] \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Note that if $\omega(L + M) \gg R$,

$$i_2 \approx \tfrac{1}{2} i_G \text{ where } i_G = \text{total grid current.}$$

Thus the out-of-balance voltage is approximately proportional to the product of grid current and leakage reactance. In practice, therefore, design must aim at a high total inductance to keep the phase errors small, and a low leakage inductance to keep the effect of grid current small.

The above analysis ignores the presence of an E.M.F. $\mu V'_C$ in series with r_a due to the feedback effect, but this is evidently quite justifiable because it has already been shown that the circuit is balanced in any case to signals in the r_a circuit.

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A Null Method of Measuring the Gain and Phase Shift of Comparatively Low Frequency Amplifiers

By T. Baldwin, A.M.I.Mech. E. * and J. H. Littlewood, M.Sc. *

THE following is a description of a method used to determine the gain and phase characteristics of low and medium frequency amplifiers. It has been found convenient in practice and gives repeatable results, without requiring more complicated equipment† than an accurate attenuator calibrated in 0.1 db steps, an oscillograph, a variable decade capacitor, a known resistor and a variable frequency oscillator giving an adequate output. The gain and phase shift in the amplifier are cancelled out by equal and opposite gain and phase shift. Consequently, the measurements are made under overall zero conditions of gain and phase shift and thus the method can be regarded as null.

In testing low and medium frequency amplifiers, the following is a common procedure:

(i) The same A.C. voltage is applied to the X and Y plates of a cathode-ray oscilloscope. For simplicity it will be assumed that push-pull deflexion is not employed. The slope of the resulting line on the C.R.T. is indicated by the points of two pins secured to the tube face by plasticine.

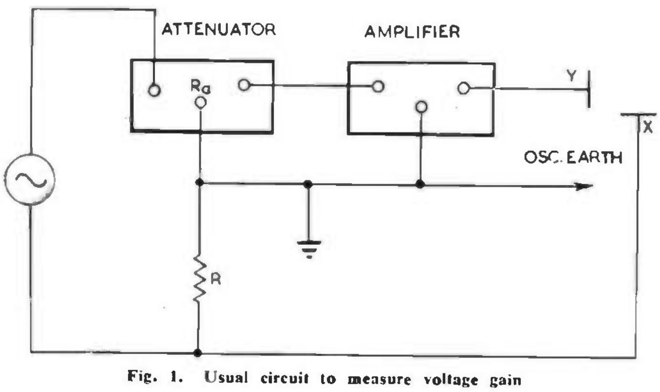

Fig. 1. Usual circuit to measure voltage gain

(ii) The circuit shown in Fig. 1 is connected up. It is usual to place a resistor R in series with the attenuator, R being greater than the characteristic impedance (R_A), of the attenuator. This is because the potential necessary to deflect the oscilloscope beam is greater than is permissible across the attenuator input. The resistor must be free from inductive or capacitative errors, and it is convenient to make it an even multiple of the characteristic impedance of the attenuator (e.g., 10 × R_A). Provided that the frequency is such that there is no phase-shift in the amplifier, the attenuator can be adjusted so that the resulting straight line on the tube face intersects the two pin points. In this condition the attenuation through R and the attenuator is the inverse of the fractional gain in the amplifier. If the fractional attenuation in the attenuator is $1/A$ the total fractional attenuation is: $R_A/A \cdot R$

and the fractional gain of the amplifier is: $A \cdot R/R_A$

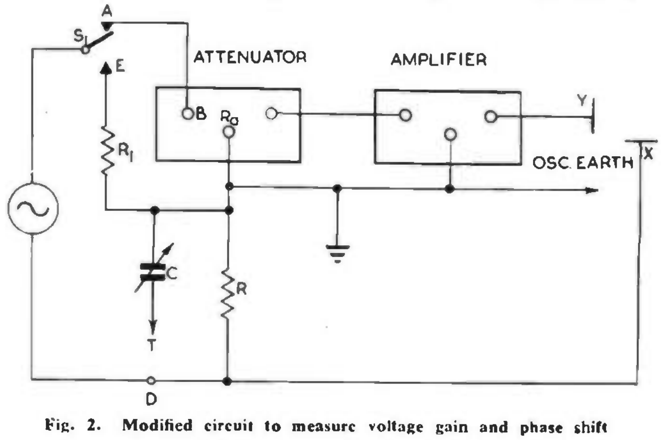

Fig. 2. Modified circuit to measure voltage gain and phase shift

Difficulties are encountered, however, when the test frequencies are such that phase shift is present in the amplifier, because the straight line on the tube face opens out into an ellipse which may become nearly circular, and under such conditions it is difficult to assign a precise direction to the major axis. The method to be described obviates this difficulty, and at all reasonable frequencies enables final

* Scientific Research Department, British Railways.

† A more elaborate equipment with an accuracy of measurement of approximately ±0.2° of phase was demonstrated by The Royal Aircraft Establishment, Ministry of Supply, at the Physical Society Exhibition in 1948.

measurements of gain and phase to be made with a straight line indication on the cathode-ray tube.

Briefly, it is arranged to alter the phase of the voltage applied across the attenuator input with respect to that applied to the X plate, so that the phase shift is equal and opposite to that introduced by the amplifier. In this condition the figure on the tube face reduces to a straight line. Manipulation of attenuator controls can then give intersection of the trace extremities by the pin points.

Fig. 2 illustrates the form of circuit used. The only essential addition to Fig. 1 is a variable capacitor (a screened decade capacitor box in parallel with a calibrated variable air capacitor). One side of this unit is earthed, the other terminal T being connected either to the attenuator input terminal B or to the X plate at D, depending on whether a leading or lagging phase shift is introduced by the amplifier. This scheme works well when the amplifier output is in phase opposition to the input, but a difficulty arises in practice when the amplifier output is approximately in phase with its input. This sets the trace in the opposite direction to the line through pin points obtained by applying the same potential to both X and Y plates.

It is comparatively easy to modify the circuit as shown in Fig. 4, the capacitor terminal T being either connected to B_1 or D. However, the resulting calculations are not quite so simple because the attenuator input potential is included in that applied to the X plate. Also, neither terminal of the capacitor is grounded when T is connected to D, thus preventing grounding of the capacitor case or else giving rise to stray capacitance to earth from the capacitor plates.

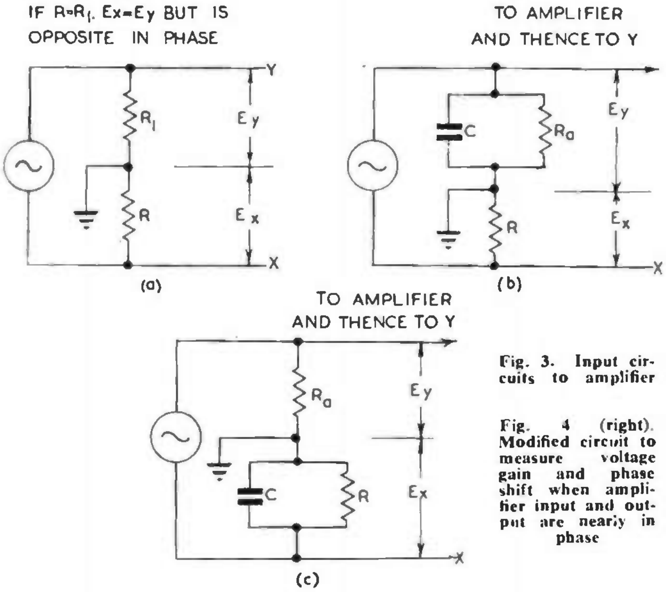

Fig. 3. Input circuits to amplifier

It seems easier to include a resistor R_1 equal to R, as shown in Figs. 2 and 3a. S_1 is switched to E and the Y plate also connected to E. This provides a push-pull output with equal and opposite potentials to the X and Y plates for use when setting the pin points, T being disconnected.

While a good 60 ohm attenuator is satisfactory with a 6,000 ohm series resistor at the lower audio-frequencies, a 75 ohm attenuator with a lower value of series resistor would probably be better when working at higher frequencies, particularly if low gains are to be measured. The provision of adequate power in the oscillator then becomes a more serious problem, and care in wiring and use of screened cable is recommended.

Theory

(*A*) *When the phase of the Steady-State Output of the Amplifier is in advance of the input. (See Fig. 3b).*

Since the current of angular frequency ω is the same for both series portions of the circuit

$$\frac{E_Y}{E_X} = \frac{\text{Impedance of } R_A \text{ and } C \text{ in parallel}}{\text{Impedance of } R}$$

$$= \frac{\dfrac{1}{1/R_A + j\omega C}}{R} = \frac{1/R_A - j\omega C}{R(1/R_A^2 + \omega^2C^2)}$$

If ϕ is the phase angle between E_Y and E_X, considering both E_Y and E_X to be due to the flow of current in the series circuit, E_Y will lag behind E_X under steady-state conditions,

$$\tan\phi = -\omega CR_A$$

$$\text{The ratio } \frac{\text{amplitude of } E_Y}{\text{amplitude of } E_X}$$

$$= \frac{\sqrt{1/R_A^2 + \omega^2C^2}}{R(1/R_A^2 + \omega^2C^2)} = \frac{1}{R\sqrt{1/R_A^2 + \omega^2C^2}}$$

Hence, if the fractional attenuation in the attenuator is $1/A$, the fractional gain of the amplifier will be

$$AR\sqrt{1/R_A^2 + \omega^2C^2}$$

and the phase shift through the amplifier will be $-\phi$, or $\tan^{-1}\omega CR_A$ will be the positive angle by which the amplifier output will be in advance of the input.

(*B*) *When the phase of the Steady-State Output of the Amplifier lags behind the input. (See Fig. 3c).*

$$\text{As before, } \frac{E_Y}{E_X} = \frac{\text{Impedance of } R_A}{\text{Impedance of } R \text{ and } C \text{ in parallel}}$$

$$= \frac{R_A}{\dfrac{1}{1/R + j\omega C}} = R_A(1/R + j\omega C)$$

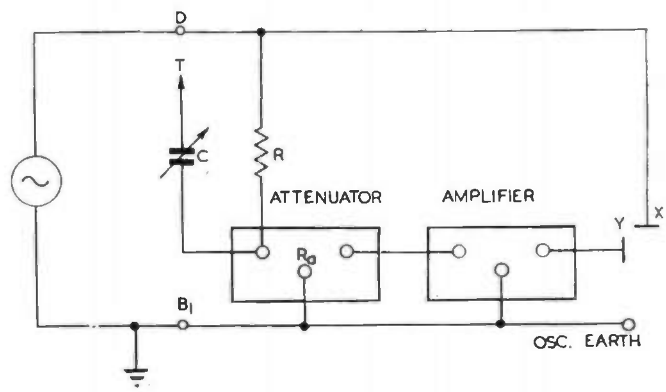

Fig. 4 (right). Modified circuit to measure voltage gain and phase shift when amplifier input and output are nearly in phase

E_Y will be in advance of E_X and $\tan\phi = \omega CR$

$$\text{The ratio } \frac{\text{amplitude of } E_Y}{\text{amplitude of } E_X} = R_A\sqrt{1/R^2 + \omega^2C^2}$$

Again taking the fractional attenuation in the attenuator to be $1/A$, the fractional gain of the amplifier will be

$$\frac{A}{R_A\sqrt{1/R^2 + \omega^2C^2}}$$

and the amplifier output will lag behind its input by an angle equal to that by which the attenuator input is in advance, i.e., by $\tan^{-1}\omega CR$.

Acknowledgments

The writers gratefully acknowledge the permission given by the Railway Executive to publish this description.

(Since this article was submitted (June, 1950), the writers' attention has been drawn to the following article referring to the same principles in the measurement of phase shift, but utilizing a different method :—
Ragazzini, J. R. and Zadeh, L. A., "A Wide Band Audio Phase Meter." Rev. Sci. Inst. 21. 145. Feb. 1950.)

A Simple Analogue Computor for Fourier Analysis and Synthesis

By J. H. Bowen, B.Sc., and T. E. Burnup, D.Sc.

A circuit containing only standard electrical components is made to solve the tedious integrals encountered in the study of the responses of electro-mechanical systems by Fourier methods. Typical applications are briefly described.

THE designer of automatic control systems often includes, in his electro-mechanical networks, devices with unknown transfer functions. For example, a primary measuring element (e.g., a thermocouple) may operate a self-balancing potentiometer, from which a re-transmitting potentiometer may feed into the rest of the control system. In the author's experience even the best manufacturers do not specify the transfer functions of these instruments. A similar difficulty frequently arises regarding the process itself, where the steady-state characteristic may be precisely known, but the differential equation governing the transient behaviour is very difficult to determine.

In such cases the value of the method of "harmonic testing" is well known, giving the steady amplitude and phase of response, for a steady sinusoidal input of constant amplitude and with frequency varied over the range of interest. The curves of amplitude $S(\omega)$ and phase $\phi(\omega)$ vs. frequency, thus obtained, exactly specify, in the case of linear circuit elements, the response to any input, and are conveniently regarded as secondary, derived parameters of the system. In this frequency characteristic form the network elements may be combined and calculations made of maximum gain and stability margins. Finally, however, the main interest will be the transient response of the whole system for various types of input. If the frequency characteristic of any input is analysed by means of the Fourier integral formula, and combined for each frequency with the response characteristic, corresponding amplitudes being multiplied together and phase angles added, the Fourier synthesis of the compound frequency characteristic is the required transient response. In particular, the response to a δ-function or unit impulse input is easily obtained since this function has a frequency characteristic of unit amplitude and zero phase angle. In this case, the transient response is given by:

$$G(\tau) = 1/\pi \int_0^\infty S(\omega) \cos [\phi(\omega) + \tau\omega] d\omega$$

when $G(\tau)$ is the response at the instant of time τsecs. after the application of the impulse.

If $S(\omega)$ and $\phi(\omega)$ are recognizable mathematical functions, the integral may either be solved directly or resolved into partial fractions, set up on the electrolytic tank, and solved by determining the residues at the poles.[1] However, as explained above, often $S(\omega)$ and $\phi(\omega)$ have been determined experimentally and graphical integration is indicated. Since this must be repeated for a reasonable number of values of the parameter τ, the calculation is laborious. This paper describes a simple analogue computor which has been designed to solve this integral with sufficient accuracy. A more accurate device has been described in Ref. 3.

A fairly obvious extension of the following reasoning also permits the computor to solve problems of Fourier analysis, thus:

$$A(\omega) = \int_{-\infty}^{\infty} G(t) \cos \omega t \, dt \quad \text{and} \quad B(\omega) = \int_{-\infty}^{\infty} G(t) \sin \omega t \, dt$$

Here $G(t)$ is a transient, non-recurrent function of time. For example, the step-function response of a servomechanism may by this means be transformed into its frequency characteristics.

Theory

The integral is re-written as:

$$G(\tau) = 1/\pi \left[\int_0^\infty S(\omega) \cos \phi(\omega) \cos \tau\omega \, d\omega - \int_0^\infty S(\omega) \sin \phi(\omega) \sin \tau\omega \, d\omega \right]$$

Put $S(\omega) \cos \phi(\omega) = A(\omega)$ and $S(\omega) \sin \phi(\omega) = B(\omega)$

Approximating to finite differences:

$$G(\tau) \approx 1/\pi \left[\sum_{\omega=\omega_1/n,\, 2\omega_1/n,\, \ldots\, \omega_1} A(\omega) \cos \tau\omega \, \delta\omega - \sum_{\omega=\omega_1/n,\, 2\omega_1/n,\, \ldots\, \omega_1} B(\omega) \sin \tau\omega \, \delta\omega \right]$$

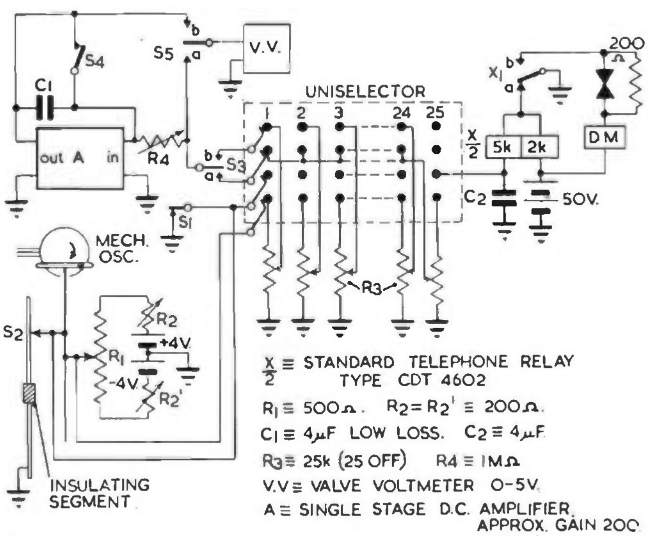

Fig. 1. Circuit details of the analogue computor

The larger n, the more accurately the approximation holds, exactly as in a mid-ordinate summation.

The integral is normally convergent, since at sufficiently high frequencies, most frequency-dependent devices become asymptotic to an attenuation-frequency slope of $-6N$ db./octave where N is an integer, dependent upon the number of time-constants involved, and on the number of steady state integrations occurring in the network. The phase at the same time approaches asymptotically $N\,\pi/2$ radians. The procedure is, therefore, either to extend the integration range to a value ω where $A(\omega)$ and $B(\omega)$ are so attenuated as to be negligible; or, preferably, to use the computor to integrate from ω_0 to ω_1 when $S(\omega_1)$ is a point on the final asymptotic slope although not necessarily greatly attenuated. The remaining integral, from ω_1 to ∞, is calculated. (See App. A).

The expressions $\sum (A(w) \cos \tau w \, \delta w$ and

$\sum B(\omega) \sin \tau\omega \, \delta\omega$ are separately set up and evaluated.

Since physical integration is most easily achieved with respect to time, the variable ω becomes time in the analogue. The basic and analogue expressions are written for comparison:

$$G(\tau) = \sum_{\omega=\omega_1/n, 2\omega_1/n, \ldots \omega_1} A(\omega) \cos \tau\omega \, \delta\omega \qquad V(p) = \sum_{t=t_1/n, 2t_1/n, \ldots t_1} Q(t) \, (V_{max} \cos pt) \, \delta t$$

$(V_{max} \cos pt)$ is obtained from a low-frequency oscillator, the same, in fact, as used for the sine-wave tests already described. $Q(t)$ is a voltage-dividing potentiometer set up to vary with time to represent the variation of $A(\omega)$ with ω. Consideration of the constants of proportionality connecting the expressions will be deferred until the actual circuit has been discussed.

Circuit Arrangements. General

The variation of $Q(t)$ is achieved by means of a Post Office type 25-contact 5-bank uniselector, one bank not being used. 24 contacts are connected each to a 3W 10k radio-type potentiometer. This was considered simpler than the alternative of a single potentiometer with 24 adjustable tapping points, since standard apparatus could be used. One bank of the uniselector is used to switch in one potentiometer at a time to avoid undue loading on the previous circuit. The uniselector is externally pulsed to complete its travel in about 5 secs. The potentiometers having been preset, the voltage appearing at the uniselector wiper follows the law $V[Q(t)]$. Also V from the oscillator $= V_{max} \cos pt$ or $\sin pt$ according to the instant at which $Q(t)$ commences on the cycle of V, when the wipers step off the 25th contact which is earthed. This is achieved by a switching interconnexion between oscillator and uniselector.

The resulting voltage $V_{max} \, Q(t) \cos \omega t$ is supplied to a standard integrator (Fig. 1) in which the amplifier will be recognized as providing a "virtual earth". $R4$ is made variable for scaling purposes as described below.

O is a mechanical oscillator, generating a sine wave of voltage on the slider of $R1$, at frequencies between 1 cycle/min. and 2 cycles/sec. according to the driven speed.

When voltage is applied to the pulsating relay, $X1a$ opens and $X1b$ closes applying voltage to the uniselector drive magnet. This does not step on until $X1b$ opens, which occurs when $C2$ has charged. On reaching contact 25, $C2$ is shorted via an earth on bank 3 and the wipers remain in this home position. The earth line to $C2$ is broken by momentarily opening $S1$ and $S2$, which are in parallel the selector then stepping on a complete cycle. $S2$ is a second oscillating wiper moving together with the main oscillator brush arm, but running on an earthed strip having an insulating segment whose position is adjusted to trigger off the uniselector at the appropriate instant according to the sine or cosine requirement.

Operating Details

The oscillator wiper is positioned at its mid-point of travel, then with $S3$ and $S5$ each set to "a", $R2$ and $R2'$ are adjusted for a balanced input shown by zero voltage on $V.V.$ The wiper is now set to maximum travel and $R3(25)$ set for full scale deflexion on $V.V.$ $S3$ is set to b, and $R3$ (1 to 24) set up to the 24 mid-ordinate values of $A(\omega)$. If these values are < 1, no difficulty arises, but if a resonant peak exists in the amplitude characteristic, a reading > 1 may be required on a voltmeter whose full scale is being treated as 0-1. If a back-off setting is provided on $V.V.$ this may be used to extend the scale, otherwise

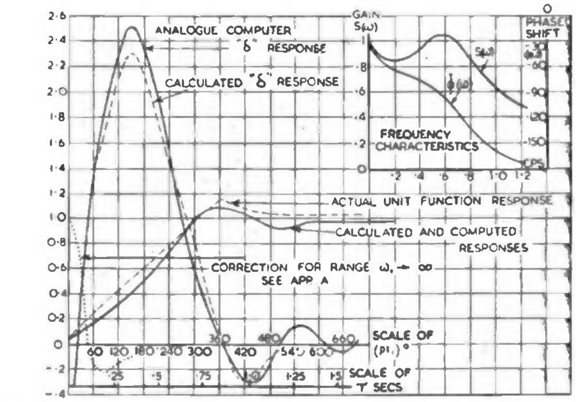

Fig. 2. Transient characteristics of a moving-coil self-recording voltmeter

$A(\omega)$ must be normalized to 1, and the final integral multiplied by the same factor. If negative values of $A(\omega)$ exist, the potentiometers representing these ordinates should be set to 0, the + and − integrals being determined separately and finally subtracted.

The integrator is now calibrated by setting $S5$ to b, $S3$ to a, and breaking $S1$ and $S2$, which allows the uniselector to step one cycle. $S4$, which is a push-button switch, is kept open during this operation, and a voltage appears on $C1$ which is a summation of the unit voltages picked off bank 2, multiplied by the time of dwell on each contact, i.e., δt.

$$G(\tau) = \sum A(\omega) \cos \tau\omega\delta\omega$$

$$V(p) = \sum Q(t) \; V \max. \cos pt \; \delta t$$

$$\omega = \frac{\omega_1}{n}, \frac{2\omega_1}{n}, \ldots \omega_1 \qquad t = \frac{t_1}{n}, \frac{2t_1}{n}, \ldots t_1$$

We make: V max. $Q(t) = A(\omega)$ $\quad \delta t = t_1/\omega_1 \; \delta\omega$

and $\tau\omega = pt$

$\therefore \quad G(\tau) = \omega_1/t_1 \; V(p)$

Now if Vc is the voltage appearing on the capacitor, and Vi is the voltage input to $R4$,

$$Vc = \sum_{t_1/24 \ldots t_1} Vi/R4 \, \delta t = 1/R4 \sum Q(t) \; V \max. \cos \text{pt.} \; \delta t = 1/R4 \; V(p1)$$

$\therefore G(\tau) = R4 \; \omega_1/t_1 \; Vc$

and $G(\tau)/\omega_1 = R4/t_1 \; Vc$. Note: $G(\tau)/\omega_1$ = average value of $G(\tau)$.

In the calibration experiment, $V_{max} \, Q(t) = 1$ and cos pt. = 1, p being zero

$$\therefore \sum_{t = t_1/24, \, 2t_1/24, \, \ldots \, t_1} (1) \, \delta t = t_1$$

$\therefore Vc1 = t_1/R4$ when $Vc1$ is the reading of $V.V.$ in the calibration experiment. $R4$ is adjusted till $Vc1 = 1$. Then Vc reads $G(\tau)$ av direct which is preferred to reading $G(\tau)$, as the average value of the same order of magnitude as V_{max}. $Q(t)$, whereas the integral will generally be greater by a factor of about 10.

Following calibration, $S3$ is set to b, the uniselector sent through one cycle, and Vc noted giving $G(o)av$. The procedure is repeated for as many values of oscillator frequency as values of τ are required in the final time plot of the transient. The appropriate value of τ in secs. is given by $\tau = (pt_1)/\omega_1$ when (pt_1) is the radian measure of the angle reached by the oscillator when the uniselector arrives at contact 24 representing t_1. In practice, at the low frequencies concerned, it is easy to adjust the speed of the

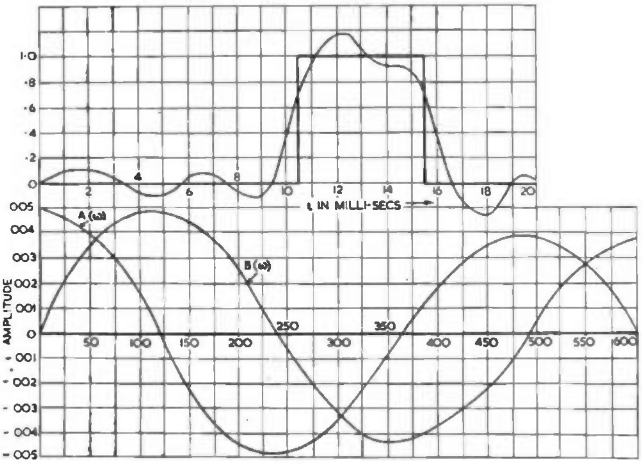

Fig. 3. Fourier analysis and re-synthesis of a short pulse

oscillator until full travel of the uniselector corresponds with multiples of, say, 1/12 cycle of the oscillator frequency. τ then increases in multiples of $T_1/12$ where T_1 is the period of the highest frequency ω_1.

Conclusions

To illustrate the accuracy of computation, Fig. 2 shows calculated and computed values of the transient response of an Elliott 0-5V recording voltmeter. The integrals of the unit impulse responses are also plotted as step-function responses, and the experimentally obtained step function response is included. Agreement is in this case better than might normally be anticipated, the sources of error being:

(1) The mid-ordinate approximation.

(2) The limitations of the standard components used throughout; e.g. non-linearity of valve voltmeter, capacitor leakage, the approximation of the "virtual earth."

(3) The voltmeter scale used which only permits reading to ± 1 per cent of full scale.

For these reasons, the expected accuracy is put at about ± 5 per cent of the maximum reading; but this is considered normally sufficient for the design calculations indicated at the beginning of this article.

Since this paper was written, a computor independently developed in the U.S.A. for the same purpose has been described.[2] The principle, however, is quite different, and in view of the enormous disparity between the costliness of the two methods, it is felt that this paper may still serve a useful purpose. Fig. 3 is included for comparison with Fig. 8(C) of that paper, the main difference being that the Gibbs effect is more strongly marked in the computor we describe. This is ascribed to the fact that the equivalent of 39 steps are used in the American device; and it is now felt that a 50 step uniselector would be a useful improvement. Also, in Fig. 2, the double transformation process has introduced double errors.

Appendix A

As an example, in the very common case of two major time lags, when $\omega > \omega_1$, $S(\omega) \to 1/T^2\omega^2$ i.e.—12 db. per octave.

Also $\phi(\omega) \to -\pi$. Then $A(\omega) = -1/T^2\omega^2$. $B(\omega) = O$.

The integral $I = 1/\pi T^2 \int_{\omega_1} \text{Cos } t\,\omega/\omega^2\, d\omega$.

When $t = o$, $I(o) = 1/\pi T^2 \Big[1/\omega \Big]_{\omega_1}^{\infty}$

$$= -1/\pi T^2\omega_1 = -2f_1\, S(\omega_1)$$

When $t > O$ $I(t) = -t/\pi T^2 \int_{t\omega_1}^{\infty} \frac{\cos t\omega\; d(t\omega)}{t^2\omega^2}$

$$= -t/\pi T^2 \left(-\left[\frac{\cos t\omega}{t\omega} \right]_{t\omega_1}^{\infty} - \int_{t\omega_1}^{\infty} \frac{\sin t\omega}{t\omega}\, d(t\omega) \right)$$

$$= -t/\pi T^2 \left(+ \frac{\cos t\omega_1}{t\omega_1} - \pi/2 + \text{Si}\,(t\omega_1) \right)$$

Where Si $(t\omega_1)$ is the sine integral function commonly tabulated.

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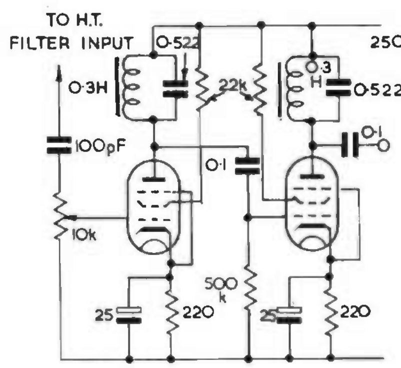
A High-Stability Single-Frequency Audio Source

By W. E. Brunt

THERE are many uses for a single-frequency audio source especially when it is simple, inexpensive and possesses frequency stability, accuracy and waveform of a fairly high order. The unit to be described possesses all the above features, yet presents few difficulties in construction.

Fundamentally it is a two-stage tuned amplifier. The input is coupled to the H.T. rectifier via a single-stage differentiator and, the amplifier being tuned to 400 c/s, the eighth harmonic is selected and amplified.

The excellence of the output waveform is largely controlled by the "Q" of the tuned circuits. In the model as constructed "Q" is approximately 20, and the peak value of all distortion and hum products does not exceed 1 per cent. This is more than adequate for all normal purposes. In fact, it is probably true to say that no simple signal generator of the conventional types can approach this performance. Furthermore, the frequency, accuracy and stability are those of the supply mains, and this (power cut periods excepted) is a fraction of 1 per cent.



The frequency of 400 c/s was chosen because it is in universal use for amplifier and receiver measurements and because it is probably the most useful for general bridge work. In construction, it is important to ensure that the coils used are sensibly of the "constant inductance" type, and that they are tuned to the desired frequency. The valves and coils were those to hand, and any others with similar characteristics may be used; in fact, EF50 or VR65 valves would be rather better.

Letters to the Editor

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

Positive Feedback in A.F. Amplifiers

DEAR SIR,—Concerning Mr. C. H. Banthorpe's contribution on audio-frequency positive feedback, I feel that your readers may possibly be interested in an amplifier which I constructed recently for A.C/D.C. operation for 12 watts output, which features negative feedback across three stages to cancel odd harmonic distortion, and positive feedback from the triode connected EF36 phase-splitter to the EF36 pentode driver stage, cathode coupled, for the combined purpose of raising the gain and balancing the upper frequencies on the cathode output side of the phase-splitter (*see below*).

It was found best to leave the phase-splitter cathode undecoupled as this gives smoother positive feedback control and a greater stable maximum gain. The extra smoothing for the first two stages is essential owing to the high gain, about 3×10^6 maximum. The .005 μF anode to anode output capacitor is essential to prevent mainly supersonic oscillation.

R. MICHAEL CROSS,
Margate, Kent.

Mr. Banthorpe replies:

DEAR SIR,—I am pleased to see that Mr. Cross uses a similar arrangement to mine to get positive feedback and his amplifier looks quite interesting in several respects. It would be informative to have his comments on positive feedback and the performance generally.

C. H. BANTHORPE,
Hayes, Middlesex.

DEAR SIR,—While not disagreeing with the general principle put forward by your contributor, Mr. Banthorpe, in your November, 1950, issue, I think the actual circuit he gives with the volume control placed between the triode and the output pentode should be used only with considerable caution.

With the circuit valves given, the triode can not give more than about 30 volts peak at the anode, when the feedback voltage developed across the 4.7k cathode resistor will be about 1.5 volts and the grid to cathode voltages also about 1.5 volts. The maximum input voltage that can be handled, therefore, cannot be more than three volts peak; and since in a conventional superhet the controlled valves will require at least 20 volts of A.V.C. bias for cut-off, there will be a serious risk that the A.F. triode will be overloaded on strong signals.

E. F. GOOD,
Malvern, Worcs.

Mr. Banthorpe replies:

DEAR SIR,—Mr. E. F. Good is quite right to point out that it is possible to overload the triode valve in the circuit given, but it is of little practical significance in the application shown, which is actually part of a small receiver using a small frame aerial. Mr. Good mentions a voltage of 30V at the triode anode, but this would never be needed, and if the volume control position is reduced to prevent overloading the output stage, the triode can cathode-follow better, and handle a bigger input voltage without distortion occurring. He also mentions 20 volts of A.V.C. bias to cut off the controlled valves, but, of course, if they were cut off there could be no A.V.C. bias. In the receiver mentioned, a signal into the frequency changer grid of approximately 10 millivolts is needed before the triode causes distortion, and this is a larger signal than is generated by most stations. In the odd situation where trouble might be experienced, the frame aerial can be rotated to prevent overloading. As a matter of interest, with this input, approximately 5V of A.V.C. bias is generated. In many applications it may be best to put the volume control in the triode input, but this has no connexion with the use of positive and negative feedback. The circuit given merely shows a method of using feedback, and also how the circuit lends itself to gain control at high signal levels with the corresponding reduction of noise due to the control, but it is probably a good thing for your readers to know how distortion can occur and I am pleased Mr. Good has raised the matter.

C. H. BANTHORPE,
Hayes, Middlesex.

Precision A.C. Voltage Stabilizers

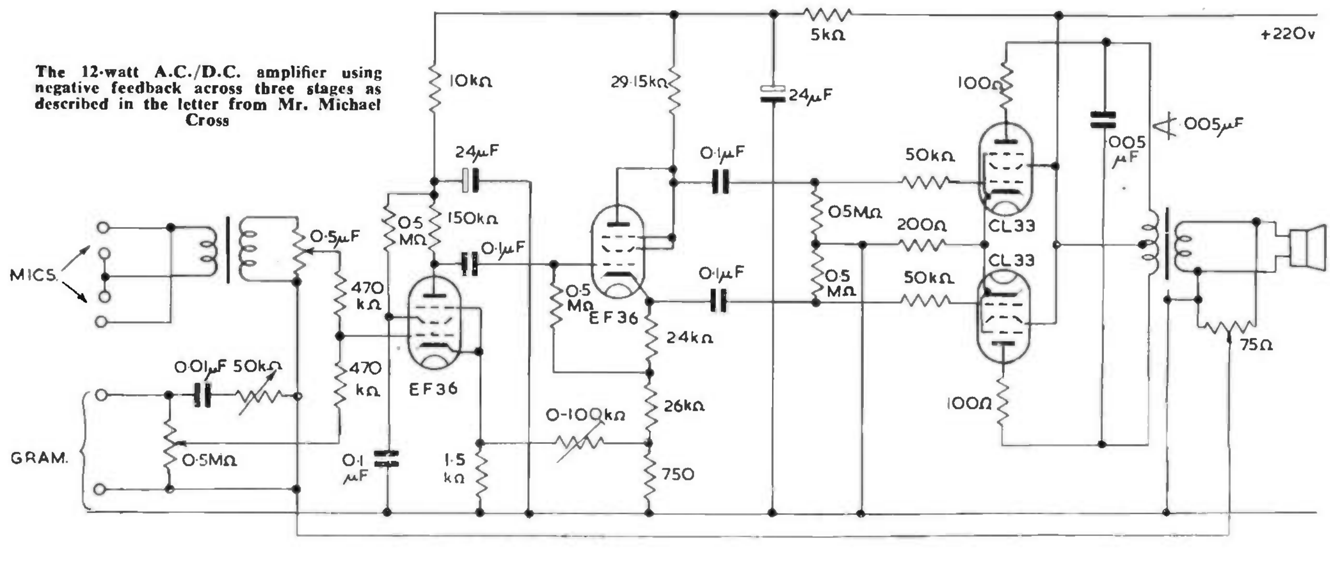
DEAR SIR,—In an article under the above heading (October issue, page 426) Dr. Patchett criticises a statement of mine[1] to the effect that a bridge voltage regulator constructed from Siemens Types 1 and 2 barretters has no appreciable thermal time lag. He appears to have overlooked the fact that this statement referred not to iron/hydrogen resistors, but to the Siemens tungsten/hydrogen type, in which the ballast action depends upon the variable gas density principle which forms the subject of British Patent No. 378877. Dr. Patchett's statement that a barretter, after a change in voltage, takes several minutes to settle down to the new equilibrium condition, applies only to the iron/hydrogen type: oscillographic tests[2] prove that for the T1 tungsten/hydrogen ballast resistor the corresponding period is 50 milliseconds.

C. MORTON,
Chelsea Polytechnic, S.W.3.

[1] *Journal Sci. Inst.* 21, p. 15, 1944.
[2] *Wireless World*, Nov. 15th. 1935.

Dr. Patchett replies:

DEAR SIR,—I am interested in the remarks of Mr. Morton concerning the Siemen's tungsten hydrogen type barretters. I have had no experience of this type and did not realize that the Siemen's barretter referred to in his reference[1] operated on a different principle, no



The 12-watt A.C./D.C. amplifier using negative feedback across three stages as described in the letter from Mr. Michael Cross

justified in a treatise on aerials, particularly since most of the information is available elsewhere. It is suggested that some of the space allocated to propagation might have been more usefully employed in discussing the measurement of the polar diagram, gain and impedance characteristics of aerials—subjects not fully covered in this book.

In spite of the minor limitations noted above, "Antenna Theory and Design" can be confidently recommended to all engineers concerned with aerial design, no matter in what part of the frequency spectrum.

W. J. BRAY

Invention and Innovation in the Radio Industry

By W. Rupert Maclaurin. Pp. 304 + xii. Macmillan, New York. 1949. Price 30s.

THIS is an unusual book which should be read by all concerned with radio and its allied subjects. At the same time stimulating and depressing, it sets out to record the histories and inventions of the great names in radio—Marconi, Fleming, de Forest, Armstrong, etc., and of the commercial giants which grew up and around them, the Marconi companies, R.C.A., General Electric, Westinghouse, A.T. & T., and so on. It recounts the story of the "perennial gale of competition" and of the endless patent litigation which followed each major advance in the art, and gives an integrated view of how the present complex structure of radio big business has evolved. Many books must have been written on the scientific and technical aspects of radio progress, but this is perhaps the first that has examined the economic factors which influence technological discovery to a greater extent than is sometimes realized.

The volume is one of a series—the Massachusetts Institute of Technology Studies in Innovation—and is written by an economist, with a scientific background, who is well qualified to lead the way through such a particularly involved topic. Engineers, commercial men and the general public alike will find this book performs a valuable service in bringing out the relations between, and the inter-dependence of, commerce and science in the field of radio. The treatment is substantially non-technical but the text is the more easily understood by those with a working knowledge of radio, and a short appendix outlines the technical elements of modern radio communication systems for lay reader.

A few chapter headings: The Impact of New Scientific Advances on Established Industry; The Process of Invention and Innovation—Marconi and the Wireless Telegraph: 1896-1920; The Role of the Large Electrical Firms in Wireless: 1912-1921; The Struggle over Patents: 1921-1928; The Perennial Gale of Competition: 1928-1941, and The Rise of Industrial Research—Radio: 1900-1941 illustrate the general scope of the book, but cannot tell of the wealth of fact and detail that is present in its pages. The names of radio organisations which are almost household names on both sides of the Atlantic constantly recur and the eternal struggle for power, the competitive frenzy, the legal fights and the commercial manoeuvring of the American radio industry during the last half-century are detailed and analysed with keen insight. It presents some amazing stories—of the court case on valves which lasted for 18 years, the mushroom growth and almost equally rapid dissolution of many firms, the ever shifting sands of commercial politics, and gives the inside story of the colossus that American radio has grown to be.

Altogether, this is a book not to be missed by all radio people, whether commercial or technical, who sometimes stop to think of the philosophical and economic aspects of their job and wonder what the future holds. It should be bought and used, not only as highly interesting general reading, but also as a well-informed text on an unusual facet of the radio game.

E. D. HART

Electronics Manual for Radio Engineers

Edited by Vin Zeluff and John Markus 879 pp. McGraw-Hill Book Company, Inc., New York, and the McGraw-Hill Publishing Co., Ltd., London. 1949. Price 57s. net.

THIS manual contains 289 of the more important articles which appeared in the American journal "Electronics" during the period 1940 to 1948, thus covering the War years when activity in research and development in the field of electronics was at its maximum. The articles are collected in 16 chapters, each covering a separate phase of electronics, viz., Antennas, Audio Equipment and Techniques, Circuit Theory, Components, D.C. Amplifiers, Filters, Ionosphere (including some articles on tropospheric propagation), Measuring Equipment and Techniques, Microwaves, Power Supplies, Production (i.e., equipment and techniques for the control of industrial processes), Receivers, Television, Transmission Lines, Transmitters and Tubes. The location of a desired article is straightforward since both an author and a subject index are included, the latter being extensively cross-indexed.

In general the emphasis is on the type of practical information needed by an engineer with a design problem to solve in a minimum of time, for example there are numerous charts, design curves, nomograms and tables of data for the rapid solution of circuit and propagation problems. A large proportion of the circuit diagrams give component values, most of the constructional diagrams are dimensioned and the performance of the circuits or components described is, in nearly all cases, illustrated by measured characteristics. Although the book will be mainly of value to engineers, it will also be of assistance to research workers in electronics by providing them with ready-made solutions to many of their circuit problems, thus freeing them for more fundamental work.

The "Electronics Manual for Radio Engineers" is particularly valuable for the broad survey it provides of the most recently developed techniques in electronics, much of the information presented is not available even in the most recently published text-books in this field. This information includes descriptions of methods, equipments and techniques developed in the research laboratories of commercial organizations, accounts of work done during the War under Government contract for the American Office of Scientific Research and Development and which has hitherto only been available through official documents and reports, together with some account of work in electronics carried out in the research laboratories of universities and colleges. Particularly important from the industrial standpoint is the chapter on the application of electronics to the control of manufacturing and mass production processes, this being a field in which the Americans have made notable contributions.

In addition to the numerous practical articles there are several theoretical analyses, relating for example to signal-to-noise and bandwidth considerations in communication systems, the design of cathode followers, filters, rectifier type power supply systems and microwave components. However, the main value of the book will undoubtedly be for its treatment of the practical aspects of the subject, the theoretical side being in general subjugated to the practical.

It would of course be unreasonable to expect a uniformly high standard of clarity, accuracy and originality throughout a book compiled from so many diverse sources, nevertheless the general standard is high for a manual of this type and is a tribute to the thoroughness of the editing.

Perhaps one of the main advantages of having the material presented in the form adopted is not only that articles on similar subjects are collected together for easy reference, but it is possible to read a given article from beginning to end without having to search among the advertisement pages for its continuation, as was the case when the articles were originally published in periodical form.

This manual is thoroughly recommended, as it will undoubtedly save its cost in many electronics research and development laboratories by reducing the man-hours spent in searching for information, and in minimizing the unnecessary duplication of work already carried out on the other side of the Atlantic.

W. J. BRAY

Elektronenoptik, Vol. I

Dr. Alexander A. Rusterholz. 249 pp. Grundzüge der theoretischen Elektronenoptik, Birkhäuser, Basel. 1950. Price 65s. (In German.)

THE new science of electron optics was well documented from its very inception. The first comprehensive treatise, by Brüche and Scherzer, appeared in 1934, only eight years after Busch had formed the magic union of the two words "electron" and "lens." which until that time appeared to be worlds apart. This was followed by the textbooks of Maloff and Epstein, Picht, Myers, Klemperer, Cosslett, Zworykin and collaborators, not to mention the numerous works on such special branches as cathode ray tubes and electron microscopes. The new treatise by Dr. Alexander A. Rusterholz, Engineer in the Electron Valve Works of the Brown, Boveri Co., Baden, Switzerland, promises to continue the tradition on an even larger scale. The first volume, which has just appeared, is a painstakingly complete re-statement of the classical parts of geometrical electron optics, in plane or rotationally symmetrical fields, without space charge. It is correct and complete, and the student who does not want to go beyond what is already well known could not find a better book. But it has also its limitations, which it shares with many other textbooks primarily written for engineers, who are presented with a living and growing branch of engineering in a frozen form, and might be led to believe that all they would have to do in practice will be the application of known formulae. This is particularly important in electron optics, which had an unusually rapid development, and has come up very early against limitations, which can be overcome, if at all, only by unorthodox means. This is a situation quite different from that in light optics, which, after 300 years, is still progressing steadily by more and more complicated applications of the same orthodox principles, aided only by new materials. But electron optics has only one medium, the electromagnetic field in vacuo, and though it is very easy to produce a "first order" lens, we know that we cannot, by orthodox means, ever produced a *corrected* lens. Hence it would be desirable, if a large textbook, like the present, would from the start present the reader with a wider view, and more general methods. It may be, however, too early to pronounce a judgment before seeing the second volume, in which the author promises to treat also non-stationary fields and space charges. In the reviewer's opinion, to be satisfactory it ought to comprise also non-symmetrical systems and at least the elements of electron wave optics.

The limited field which forms the subject of this first volume is treated with great thoroughness, as may be judged from its chapters: 1. The electron in electric and magnetic fields; 2. The electron-optical refractive index; 3. Rotationally symmetric fields; 4. Electron trajectories in rotationally symmetrical fields; 5. Electric lenses; 6. Magnetic and electro-magnetic lenses; 7. The aberrations; 8. Two-dimensional fields. Electron prisms; and 9. Electron mirrors. There are ample references, and a subject index.

The high price of the book will probably restrict the circulation in this country, as far as the general and individual reader is concerned, but it may be recommended to university and laboratory libraries.

D. GABOR

Microwave Measurements

By H. M. Barlow and A. L. Cullen. 399 pp. Constable. 1950. Price 30s.

THE only text-books on measurements at centimetric wavelengths so far published are relatively expensive American works and the appearance of this volume will be welcomed by microwave workers in this country. Microwave measurements involve a more detailed examination of electromagnetic fields than is the case at longer wavelengths and so the techniques are very different. In the first three chapters an outline of the theory of waveguides and cavity resonators is given: it would be impossible to discuss these without reference to Maxwell's equations, but the non-mathematical reader need not be afraid of finding the treatment beyond him. The introduction of the analogy with transmission lines is introduced at an early stage and a detailed discussion of the circle diagram follows. The many examples of calculations which follow later in the book bring out very clearly the advantages to be obtained from use of the circle diagram.

The first measurements to be considered are those of wavelength and frequency, and as elsewhere in this book the emphasis is upon general principles rather than descriptions of particular pieces of apparatus, for which ample references are given. The cavity resonator method is the most fully described, but an omission which might well be rectified in a future edition is the use of this method for the determination of the velocity of electromagnetic waves.

One of the commonest measurements required is that of a standing wave ratio and it is fitting that one of the longest chapters should be devoted to this. A more exhaustive analysis of the effect of the probe on the accuracy of measurement than has hitherto been available is given and will be of value to anyone who habitually uses a standing wave gear. Much useful information on the mechanical tolerances required in order to achieve a given standard of accuracy is given in the section on constructional methods. Standing wave measurements are usually the preliminary to the matching of a transmission system and this is treated in the following chapter. The bulk of the discussion, much of which is new, is concerned with the general case and a minor criticism is that there is no detailed example of the application to a particular problem. The question of the bandwidth of the match, a most important one in practice, merits a rather fuller treatment than is given.

The remaining chapters deal with attenuation, power, the properties of materials and the measurements arising with receivers, transmitters and aerials. The section on attenuators is particularly interesting for the circuit analogy explaining the apparent paradox, that the power in an attenuator is transmitted by an attenuated mode.

A very pleasing feature of this book is the large number of experimental values and curves used to illustrate the measurements described.

The authors are to be congratulated on producing a book which may profitably be read by anyone working in this field.

J. BROWN

Electrical Engineers' Companion

268 pp. 2nd Edition. London Electric Wire Co. and Smiths, Ltd. 1950. Price 5s.

THIS attractive little pocket book of useful electrical data has been brought up to date in this edition, and arranged and indexed for easy reference to any specific subject.

Modern data has been collated relating to bare and insulated wires and cables from many sources, including the B.S.I., I.E.E., and E.R.A.

Notes from the Industry

The Physical Society's 35th Annual Exhibition of Scientific Instruments and Apparatus will be held from Friday, 6, to Wednesday, 11 April, 1951, excluding Sunday.

This year both the Royal College of Science Main Building, Imperial Institute Road, and the Huxley Building, Exhibition Road (opposite Science Museum) will be used. On Friday morning the Exhibition will be open for members of the Society and the Press only, and all tickets will be valid for entry into both buildings.

This Exhibition takes place before the opening of the Festival of Britain, but physicists from abroad who intend to visit the latter may like to make arrangements to come to England earlier as the Exhibition affords one of the most important displays of scientific achievement which is held in Great Britain, and is unique in showing side by side the work of academic scientists, commercial instrument makers and research workers in Government and other laboratories. It will also provide a convenient opportunity for conversations and contacts with technical representatives of British firms and associations.

Discourses will be delivered by eminent scientists on four days of the Exhibition, and the prize-winning models of the Society's Craftsmanship and Draughtsmanship Competition will be on show. This competition, which is open to apprentices and others under the age of 22 years, is organized to stimulate the interest of young craftsmen and draughtsmen in industrial firms, technical colleges and Government departments.

A Handbook of the Exhibition, containing full descriptions of all exhibits will be obtainable in early March from the Physical Society at 1, Lowther Gardens, Prince Consort Road, London, S.W.7.

Obituary. Mr. Percy Good, C.B.E., M.I.E.E., died on December 2. He was a director of the British Standards Institution, and had been connected with the Institution for 37 years. Mr. Good was also a past president of the Institution of Electrical Engineers.

B.S.I. New Director and Secretary. Mr. H. A. R. Binney, C.B., has been appointed director and secretary in succession to the late Mr. Percy Good, C.B.E.

Lectures on Ultrasonics have been arranged at the Polytechnic, 307-311 Regent Street, London, W.1, commencing March 2. There will be four lectures, and the fee for the course is 10s. The syllabus covers fundamentals, generation and reception of ultrasonic waves, and applications of ultrasonics. Full details can be obtained from the Polytechnic.

New R.A.M.A.C. Secretary General. Mr. E. Fost has been appointed Secretary General of R.A.M.A.C. in succession to Mr. J. Connell, who is now retiring from the post, which he has held since the formation of the Association. R.A.M.A.C. (Radio Marine Associated Companies) is a world organization of companies operating marine radio services. The resources of the member companies are co-ordinated to further the development of ships' radio equipment and aids to navigation.

Mr. Fost has been associated with marine radio for 25 years. His office will be at the R.A.M.A.C. headquarters, 109 Eaton Square, London, W.1.

New Chairman for Standard Telephones and Cables, Ltd. Sir Thomas G. Spencer, M.I.E.E., managing director of Standard Telephones and Cables, Ltd., has been elected chairman of the board of directors of the company. He succeeds the late Sir Frank Gill, K.C.M.G., O.B.E., who died on October 25, 1950.

With Standard Telephones and Cables, Ltd. (formerly the Western Electric Company, Ltd.) since 1907, Sir Thomas was called upon to take charge of the company in 1932, and will continue in the capacity of managing director in addition to holding the office of chairman.

The R.C.A. Manual RC-16. The new R.C.A. Receiving Tube Manual, RC-16, which incorporates many new features reflecting new developments in electronics, has been completely revised, expanded, and brought up to date. Containing over 300 pages, it is 25 per cent larger than the previous RC-15 edition which it supersedes.

The same complete coverage of technical data contained in previous editions, ranging from elementary theory to descriptions of latest receiving-tube applications, has been continued and enlarged in the new RC-16. Detailed technical information is provided on more than 460 R.C.A. receiving tubes and cathode ray tubes including many discontinued types. The section on valve and circuit theory has been expanded and includes formulae and examples for calculation of power output, load resistance and distortion for several classes of amplifier service as well as cathode follower design information. Television coverage includes C.R.T. installation data and handling information.

Orders for single copies of the RC-16 Tube Manual may be placed with R.C.A. Photophone, Ltd., 36 Woodstock Grove, W.12. The price of the manual is 5s. 6d. post free.

American Order. Messrs. Tenaplas, Ltd., have recently received orders covering a total of over 950 miles (five million feet) of polythene-covered and P.V.C.-covered twin flat wire from a firm in New York. The wire is to be used for electrical purposes.

PUBLICATIONS RECEIVED

HELVIN LIST B.209 describes the applications of this special type of P.V.C. made by Hellermann Electric, Ltd., Tinsley Lane, Crawley, Sussex, which include a wide range of articles for the radio, electronic, automobile and aircraft industries either in the form of mouldings or by other special processes described in this booklet.

SCIAKY PMCO2ST THE THREE PHASE MODU WAVE WELDER concerns a new resistance welder for spot welding aluminium, etc., developed by Sciaky Bros., 4915 West 67th Street, Chicago 38, Illinois, U.S.A., from whom a brochure may be obtained.

EDISWAN MICROFILM READERS is a brochure describing these instruments, which provide high quality reproduction from all normal 35 mm. microfilm frame with easy manipulation, and do not necessitate a dark room. Full details from the Edison Swan Electric Co., Ltd., 155 Charing Cross Road, London, W.C.2.

G.B. 16 MM. ENTERTAINMENT FILM CATALOGUE includes a section on industrial films, which covers steel, optical glass, the manufacture of plastics, etc. Civics and social welfare are also subjects of interest. It is obtainable from G.B. Equipments, Ltd., Mortimer House, 37-41 Mortimer Street, London, W.1.

BURGESS MICRO-SWITCHES CATALOGUE NO. 50 is a brochure describing the types made by Burgess Products Co., Ltd., Micro-Switch Division, Sapcote, Leics., and includes schematic diagrams of the switches.

" FLUON " POLYTETRAFLUOROETHYLENE is a booklet concerned with the manufacture of this type of plastic. It has previously been developed commercially in the U.S.A., and is now made in Britain by Imperial Chemical Industries, Ltd., Gloucester House, 149 Park Lane, London, W.1.

ELECTRICAL ENGINEERING ABSTRACTS, DECEMBER 1950. This booklet is Section B of " Science Abstracts " which are edited and issued monthly by the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

EKCO CAR RADIO is a catalogue of the types of car radio made by Ekco's. It gives full technical details of their parts, etc., and can be obtained from E. K. Cole, Ltd., Ekco Works, Southend-on-Sea, Essex.

WIGGIN NICKEL ALLOYS NO. 328 features various types of furnace equipment, and the heat-resisting uses of high nickel alloys. Other items of general interest are uses of these materials in glass blowing, modern engine fuel lines, food processing, hospital equipment, and chemical plant. Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham 16.

" JUAN DE LA CIERVA " FOUNDATION FOR TECHNICAL RESEARCH—Its Organization and Development. This most attractive and beautifully illustrated brochure describes this Spanish technical Foundation. It lays out its purpose, and describes its centres and institutes which cover a wide range such as scientific apparatus, fuel research, welding, iron and steel, electronics and rationalization. Institute of Electronics, Rios Rosas 54, Madrid, Spain.

EASIBIND FOLDERS

Readers are reminded that a few of the old size Easibind Folders are still available for binding their 1950 issues of "ELECTRONIC ENGINEERING", and can be obtained from the Circulation Department, price 12s. 6d. postage 6d. Easibind Folders for the new size journal are also available at the same price.

1950 INDEX

The 1950 Index, Volume 22, is still available. Copies may be obtained without charge and post free, on application to the Circulation Department of this Journal.

MEETINGS THIS MONTH

INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

Date: February 1. Time: 5.30 p.m.
Lecture: Standardization and Simplification in the Electrical Industry.
By: J. T. Moore, B.Sc.
Lecture: An Organization for Internal Standardization in a Large Manufacturing Company.
By: P. J. Daglish, B.Sc.

Date: February 14. Time: 6.30 p.m.
Held at: The Central Hall, Westminster, S.W.1.
Faraday Lecture: Lamps and Lighting—A Record of Industrial Research.
By: L. J. Davies, M.A., B.Sc.

Radio Section

Date: February 7. Time: 5.30 p.m.
Lecture: Radio-Valve Life Testing.
By: R. Brewer.

Date: February 19. Time: 5.30 p.m.
Discussion: Is there an Optimum Speed for a Gramophone Record?
Opened by: G. F. Dutton, Ph.D., B.Sc.(Eng.).

Measurements Section

Date: February 13. Time: 5.30 p.m.
Lecture: The Inductor Compass.
By: A. Hine, B.Sc.Tech.

Date: February 27. Time: 5.30 p.m.
Discussion: Electrical Measurement by Thermal Effects.
Opened by: Professor J. Greig, M.Sc., Ph.D., L. G. A. Sims, D.Sc., Ph.D., and J. G. Freeman, M.A., Ph.D.

Utilization Section

Date: February 15. Time: 5.30 p.m.
Lecture: The Dimming of Low-Pressure Discharge Lamps.
By: C. E. Williams, B.Sc.

Informal Meeting

Date: February 12. Time: 5.30 p.m.
Discussion: Inventor, Engineer, and Manager.
Opened by: P. P. Eckersley.

Supply Section

Date: February 21. Time: 5.30 p.m.
Lecture: Transient Theory of Synchronous Generators Connected to Power Systems.
By: B. Adkins, M.A.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: February 6. Time: 5 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: Some Aspects of Electronic Circuit Design.
By: S. W. Broadhurst and A. W. M. Coombes, Ph.D.

Informal Meeting

Date: February 21. Time: 5 p.m.
Held at: Conference Room, 4th Floor, Waterloo Bridge House, S.E.1.
Lecture: Public Speaking.
By: A. K. Robinson, M.I.E.E.

TELEVISION SOCIETY

Date: February 1. Time: 7 p.m.
Held at: Cinema Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.
Lecture: On the Technique of Television Interviewing.
By: Leslie Mitchell.

Date: February 23. Time: 7 p.m.
Held at: The Cinema Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.
Lecture: Television from Calais—The First Cross-Channel Broadcast.
By: W. D. Richardson and W. N. Anderson.

Engineering Group

Date: February 8. Time: 7 p.m.
Held at: The Cinema Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.
Lecture: The First British Multi-Channel Receiver.
By: W. D. Asbury, K. M. B. Wright and W. M. Lloyd, B.Sc.

SECRETARIES OF ASSOCIATIONS

INSTITUTION OF ELECTRICAL ENGINEERS

The Secretary, Institution of Electrical Engineers, Savoy Place, W.C.2.

Cambridge Radio Group

G. E. Middleton, M.A. University Engineering Laboratory, Cambridge.

North-Eastern Radio and Measurements Group

G. A. Kysh (Asst. Sec.), Carliol House, Newcastle-on-Tyne, 1.

North-Western Radio Group

A. L. Green (Asst. Sec.), 244 Brantingham Road, Chorlton-cum-Hardy, Manchester, 21.

South Midland Radio Group

W. H. Brent, B.Sc., Regional Director's Office, Midlands Region (G.P.O.). Civic House, Great Charles Street, Birmingham, 3.

BRITISH INSTITUTION OF RADIO ENGINEERS

The General Secretary, 9 Bedford Square, London, W.C.1.

West Midlands Section

R. A. Lampitt, A.M.Brit.I.R.E., 20 Northfield Grove, Merry Hill, Wolverhampton.

INC. RADIO SOCIETY OF GREAT BRITAIN

General Secretary, New Ruskin House, Little Russell Street, W.C.1.

BRITISH SOUND RECORDING ASSOCIATION

Richard W. Lowden, "Wayford," Napoleon Avenue, Farnborough, Hants.

TELEVISION SOCIETY

Lecture Secretary: T. M. Lance, 180 Bromley Road, Beckenham, Kent.

Engineering Group

G. T. Clack, 10 Tantallon Road, Balham, London, S.W.12.

RADAR ASSOCIATION

The Secretary, 83 Portland Place, London, W.1.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

W. H. Fox, A.M.I.E.E., Engineer-in-Chief's Office (T. P. Branch), Alder House, E.C.1.

INSTITUTION OF ELECTRONICS

Lecture Sec.: W. Summer, 31 Beech Road, Bournville, Birmingham, 30.

North-West Branch

W. Birtwistle, 17 Blackwater Street, Rochdale, Lancs.

SOCIETY OF RELAY ENGINEERS

T. H. Hall, M.Brit.I.R.E., 23 Dalkeith Place, Kettering, Northants.

SOCIETY OF INSTRUMENT TECHNOLOGY

L. B. Lambert, 55 Tudor Gardens, London, W.3.

SOCIETY OF INSTRUMENT TECHNOLOGY

Date: February 27. Time: 6.30 p.m.
Held at: Manson House, Portland Place, London, W.1.
Lecture: The Measurement of Surface Temperature.
By: Dr. R. C. Parker.

BRITISH INSTITUTION OF RADIO ENGINEERS

London Section

Date: February 21. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.
Lecture: Electronics and Air Transport.
By: C. H. Jackson, B.Sc., A.F.R.Ae.S., A.M.I.Mech.E.

Scottish Section

Date: February 1. Time: 6.45 p.m.
Held in: Edinburgh.
Lecture: Multi-Station V.H.F. Communication Systems using F.M.
By: W. P. Cole, B.Sc., and E. G. Hamer, B.Sc.

Merseyside Section

Date: February 7. Time: 7 p.m.
Held at: Electricity Service Centre, Whitechapel, Liverpool.
Lecture: A Transmitter for an Experimental 8-Channel Wire-Broadcasting System.
By: R. G. Kitchenn, B.Sc.(Eng.).

South Midlands Section

Date: February 14. Time: 7.15 p.m.
Held at: East Midlands Electricity Board, Coventry.
Lecture: A Survey of Television Development and its Problems.
By: H. J. Barton-Chapple, B.Sc.

North Eastern Section

Date: February 14. Time: 6 p.m.
Held at: Neville Hall, Westage Road, Newcastle-on-Tyne.
Lecture: The Use of Foster's Theorem in Circuit Design.
By: E. Williams, Ph.D.

West Midlands Section

Date: February 28. Time: 7 p.m.
Held at: Wolverhampton and Staffs. Technical College, Wulfruna Road, Wolverhampton.
Lecture: Power Rectifiers.
By: J. C. Milne.

BRITISH SOUND RECORDING ASSOCIATION

Date: February 16. Time: 7 p.m.
Held at: Royal Society of Arts, John Adam Street, London, W.C.2.
Lecture: The Application of Elementary Mechanics to Sound Recording.
By: J. F. Doust.

INSTITUTION OF ELECTRONICS

Midlands Branch

Date: February 6. Time: 7 p.m.
Held at: Warwick Room, Imperial Hotel, Temple Street, Birmingham 2.
Lecture: Electronic Aids in Engineering, Research and Development.
By: J. R. Cornelius.

RADAR ASSOCIATION

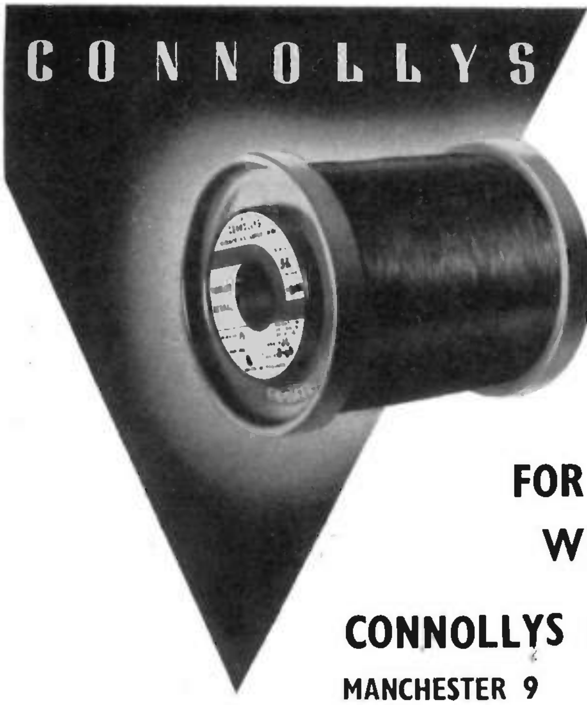
Date: February 6. Time: 7.30 p.m.
Held at: The Albert Tavern, Victoria Street, London, S.W.1.
Monthly Meeting.

East Anglian Branch

Date: February 24.
Held at: Lamb Inn, Norwich.
Monthly Meeting.

INC. RADIO SOCIETY OF GREAT BRITAIN

Date: February 23. Time: 6.30 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: Post-War Developments in Television.
By: H. A. M. Clark, B.Sc.(Eng.), A.M.I.E.E.



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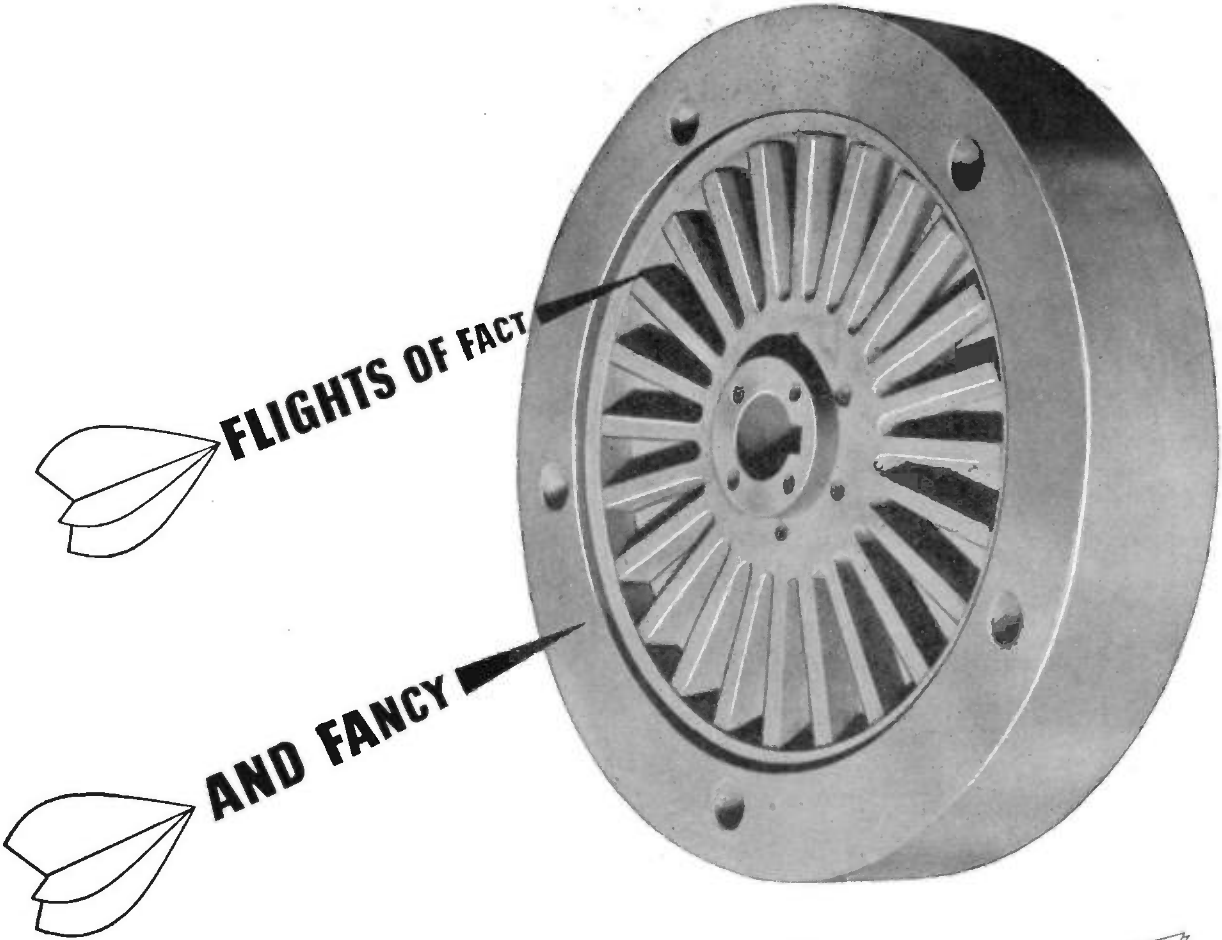
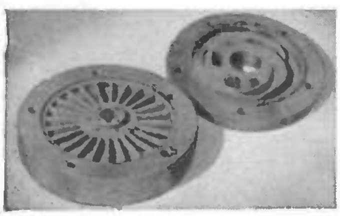


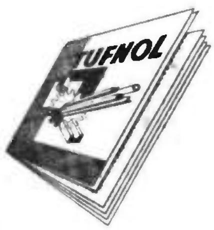
Not by any stretch of imagination would Tufnol make a good dart-board, yet our illustration, which is part of a chemical pump, serves a double purpose. It proves two points—the accuracy and intricacy possible in machining Tufnol and its resistance to corrosion.

But Tufnol combines many other qualities ideally sought after in metals and hardwoods but seldom realised in either. It is only half the weight of aluminium yet structurally strong enough to work sympathetically with steel; it is an excellent electrical insulator, yet it will not splinter or crack under impact. Neither exposure to corrosive atmospheres nor extremes of climatic conditions have any appreciable effect on its composition or finish. Given ordinary workshop facilities, any component can be easily produced from standard Tufnol sheets, tubes, rods, angles, or channels. Specially moulded blanks or finished parts can also be supplied to your exact specification. Can you afford to make-do without Tufnol when others are making progress with it?



An open view of a chemical pump made of Tufnol

CHALK THIS UP TO TUFNOL



You are welcome to apply for any or all of the handbooks containing useful data, particular uses, and in fact everything known about Tufnol. But what may be more important to you is our keenness to co-operate in any technical development incorporating its use in new ways. Why not outline your requirements in a letter—and send it TODAY.

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Osram caesium antimony cells, vacuum and gasfilled, have a higher sensitivity level to artificial light than the cells of the caesium silver oxide type, and for most purposes are, therefore, preferable.

The minimum sensitivityof the vacuum cell to radiation from a tungsten lamp operating at 2850°K is 25 micro-amperes per lumen, and of the gasfilled cell 120 micro-amperes per lumen at 90 volts with a gas factor not exceeding 8. These are guaranteed minima and most cells have considerably higher response.

The caesium antimony cathode has a peak response in the blue end of the visible spectrum so that for any application involving blue light the sensitivity is vastly greater than the above figures would imply.

The cell is also far more sensitive than the caesium silver oxide type for any application involving daylight as the light source.

Even though the point of spectral response is farther removed from the peak of the radiant energy curve of a tungsten lamp than that of the caesium silver oxide cell, the average sensitivity level, as mentioned above, is higher.

The caesium antimony cell has no response to infra-red and cannot, therefore, be used for applications involving such invisible radiation. Even this characteristic is not without its advantages. Infra-red sensitivity is known to be closely associated with dark current which contributes to background noise in sound reproduction and similar applications.

The cathode is deposited on the wall of the bulb, which construction removes a possible source of microphony. The vacuum and gasfilled cells, therefore, have a much reduced noise level.

For further information write to: Osram Valve and Electronics Dept., Magnet House, Kingsway, W.C.2.

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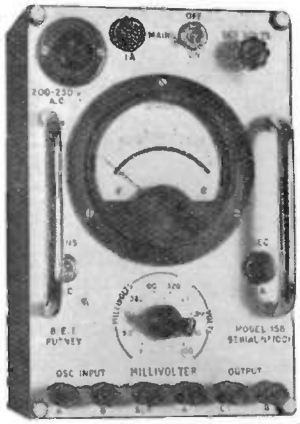

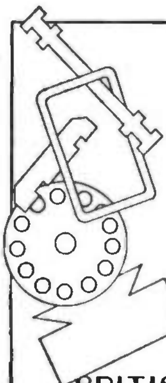

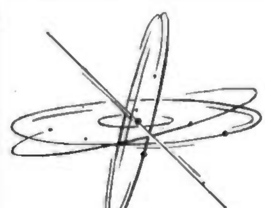

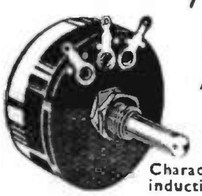

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