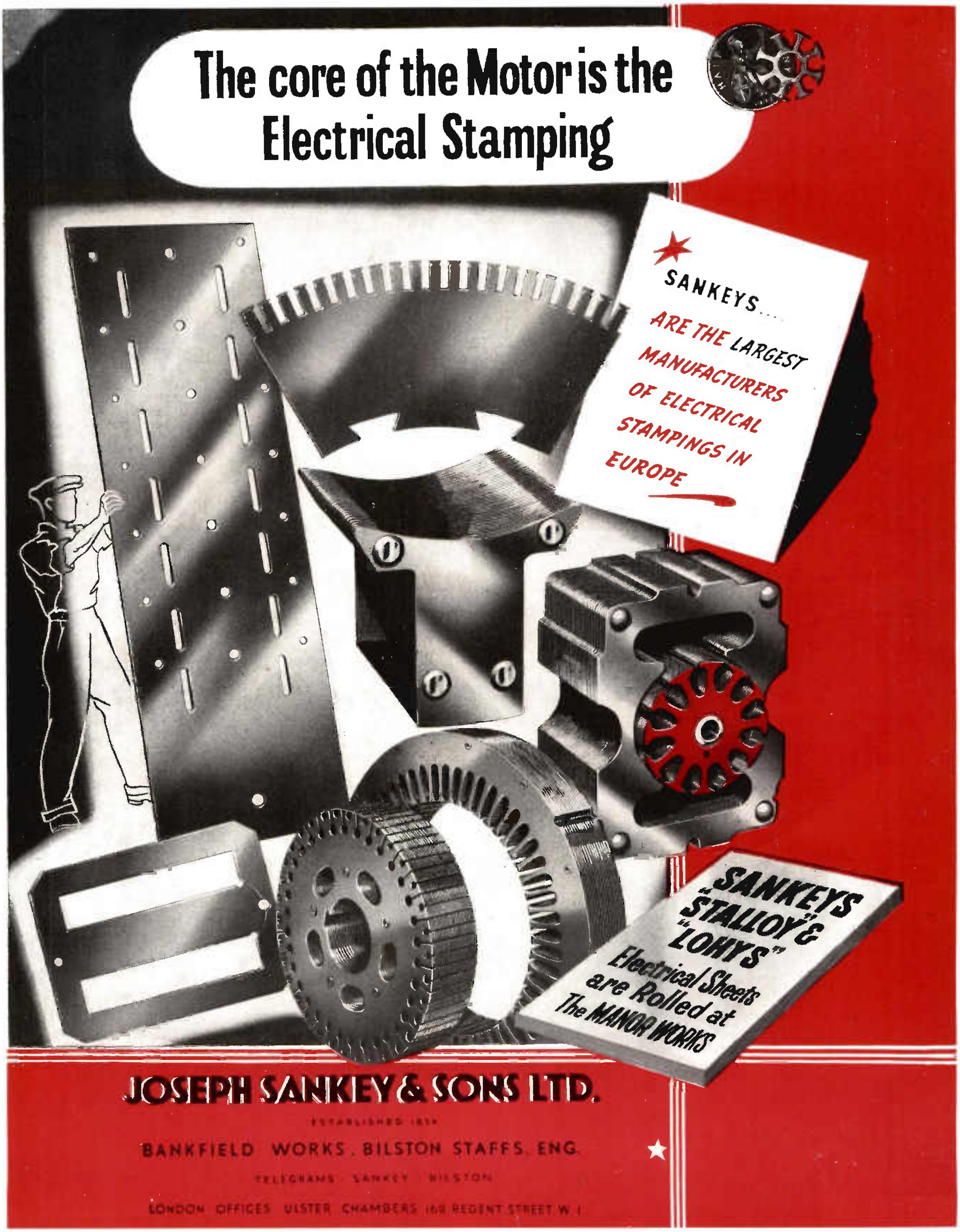
Electronic Engineering

OCTOBER 1951

TWO SHILLINGS


The core of the Motor is the Electrical Stamping
SANKEYS....
ARE THE LARGEST MANUFACTURERS OF ELECTRICAL STAMPINGS IN EUROPE
SANKEYS "STALLOY" & "LOHYS" Electrical Sheets are Rolled at The MANOR WORKS
JOSEPH SANKEY & SONS LTD.
BANKFIELD WORKS, BILSTON STAFFS, ENG.
TELEGRAMS: SANKEY BILSTON
LONDON OFFICES ULSTER CHAMBERS REGENT STREET W.1

CLASSIFIED ANNOUNCEMENTS

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

OFFICIAL APPOINTMENTS

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

ADMIRALTY. Vacancies exist for Electrical and/or Mechanical Engineering Draughtsmen in Admiralty Research and Development Establishments located in the vicinity of Weymouth, Portsmouth, Teddington (Middlesex) and Baldock, Herts. Draughtsmen experienced in light current, electro-mechanical, precision mechanical and electronic equipment are particularly needed. Candidates must be British subjects of 21 years of age and upwards, who have had practical workshop experience (preferably an apprenticeship) together with Drawing Office experience. Appointments will be in an unestablished capacity, but opportunities may occur for qualified staff to compete for established posts. The salaries offered depending on age, experience, ability and place of duty will be within the range £320-£560 p.a. Hostel accommodation is available at some Establishments. Applications, stating age and details of technical qualifications, apprenticeship (or equivalents) Workshop and Drawing Office experience, should be sent to Admiralty (C.E.11. Room 88) Empire Hotel, Bath, quoting DM/R.D. Original testimonials should not be forwarded with application. Candidates required for interview (at London or Bath whichever is nearer) will be advised within two weeks of receipt of application. W 2111

APPLICATIONS are invited by the Division of Atomic Energy (Production) for the following appointments at Risley:- Post (A) Electrical Engineer to design electrical equipment including H.T. and L.T. switchgear, substations, and internal installations for large chemical factories. Post (B) Instrument Engineer to undertake the design, provision, and maintenance of instruments used for the measurement of radioactivity and for the control and recording of pressures, temperatures, and the flow of liquids and gases in pipes. For post (A), candidates must have served an electrical engineering apprenticeship and have either an Honours Degree in engineering, corporate membership of the Institution of Electrical Engineers or equivalent qualifications. They must have had experience of factory electrical installations. For post (B) candidates must have served an apprenticeship with an instrument manufacturing firm and have either an Honours Degree in engineering, corporate membership of one of the Institutions of Mechanical or Electrical Engineers, or equivalent qualifications. They must have had experience of instrument manufacture and in duties similar to those outlined. Salary will be assessed according to qualifications and experience within the range £570-£720 p.a. (if over 30) and according to age within the range £330-£545 p.a. (if under 30). There is a voluntary superannuation scheme. Applications to Ministry of Supply, D.At.En. (P), Risley, Nr., Warrington, Lancs. stating post applied for. W 2135

ASSISTANT (SCIENTIFIC) CLASS: The Civil Service Commissioners give notice that an Open Competition for pensionable appointment to the basic grade will be held during 1951. Interviews will be held throughout the year, but a closing date for the receipt of applications earlier than December, 1951, may eventually be announced either for the competition as a whole or in one or more subjects. Successful candidates may expect early appointments. Candidates must be at least 17½ and under 26 years of age on 1st January, 1951, with extension for regular service in H.M. Forces, but other candidates over 26 years with specialized experience may be admitted. All candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects: (i) Engineering and physical sciences. (ii) Chemistry, bio-chemistry and metallurgy. (iii) Biological Sciences. (iv) General (including geology, meteorology, general work ranging over two or more groups (i) and (ii) and highly skilled work in laboratory crafts such as glass-blowing). Salary according to age up to 25—Men £215 (at 18) to £330 (at 25)—£455; rather less in the provinces and for women. Opportunities for promotion. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S. 59/51. Completed application forms should be returned as soon as possible. W 2156

BRITISH ELECTRICITY AUTHORITY. Eastern Division (Technical Staff). Applications are invited for the following appointments in the Technical (Electrical) Department at Divisional Sub-Headquarters, West Farm Place, Cockfosters: General Assistant Engineer (Communications Section). The duties of the post will be assisting with the installation, maintenance and testing of communications equipment in Generating Stations and Sub-Stations. Applicants should be Graduate or Corporate Members of the Institution of Electrical Engineers and experience with carrier current telephony channels and the adjustment of automatic switchgear would be an advantage. Salary range in accordance with the N.J.B. Agreement, Schedule C, Grade 8, Class AX. (£437-£569 per annum) plus London Weighting. The commencing salary will depend upon qualifications and experience. The appointment will be superannuable in accordance with the British Electricity Authority and Area Boards Superannuation Scheme. Forms of application may be obtained from the Divisional Controller, British Electricity Authority, Eastern Division, Northmet House, Southgate, N.14, to whom completed forms should be sent to arrive not later than 12th October, 1951. Envelopes should be endorsed "General Assistant Engineer (Communications Section)" W.N.C. Clinch, Controller. W 2145

ELECTRICAL ENGINEERS and Physicists are invited by the Ministry of Supply to apply for the following appointments in the Scientific Officer Class at a Research and Development Establishment near London. Senior Scientific Officer 1. Electrical Engineers (2) with special qualifications in radio communications and experience in the engineering of development prototypes. (D 390/51A). 2. Physicist with experience in electronic circuitry for research into the measurement of high speed transients. (A 245/51A.) 3. Physicist with experience of optical and electronic techniques, and with an interest in fluid mechanics, for work on aerodynamics problems including wind tunnel investigations. (A 246/51A). Scientific Officer 4. Electrical Engineer or Physicist with interest in the application of electronic methods to optical instrumentation techniques. (D 392/51A.) 5. Electrical Engineer or Physicist for work on high speed electronic calculating machine. (D 391/51A.) Candidates should possess a 1st or 2nd class Honours Degree in Physics or Electrical Engineering or equivalent qualification. For the senior grade the minimum age is 26 and at least 3 years' post-graduate research experience is required. For post 1 an engineering apprenticeship or industrial experience would be of advantage. Salary will be determined on age and on an assessment of the successful candidate's qualifications and experience within the ranges: Senior Scientific Officer—£720-£910, Scientific Officer—£380-£620. Rates for women somewhat lower. Posts are unestablished but carry benefits under F.S.S.U. Application forms obtainable from Ministry of Labour and National Service, Technical & Scientific Register (K), York House, Kingsway, W.C.2, quoting the appropriate reference number. Closing date 24th October 1951. W 2124

ELECTRONIC ENGINEERS required by Government Department. Candidates should have knowledge of general electronic or pulse technique or telecommunications up to H.N.C. (or equivalent standard), with subsequent electronic experience. Duties: Maintenance and fault tracing and development work. Location: Cheltenham, Glos. Salary: Within the scale of £240-£570 per annum (Provincial Rate). Write for application form to Ministry of Labour and National Service, Technical & Scientific Register (K), York House, Kingsway, W.C.2, quoting reference D263/51A. Closing date 12th October 1951. W 2115

ELECTRONIC ENGINEER or Physicist required by the Division of Atomic Energy (Production) to take charge of a group concerned with the maintenance and modification of electronic instruments at Windscale Works, Sellafield, Cumberland. Candidates must have either an Honours Degree in engineering or physics, corporate membership of the Institution of Electrical Engineers or associateship of the Institute of Physics, or, alternatively have attained high professional standing in the electronics field. They must in any case have had wide experience in the repair and maintenance of electronic equipment, have a sound knowledge of electronic principles and pulse techniques and, preferably, have had experience in the management of a group concerned with electronic instrument maintenance. Salary will be assessed according to qualifications and experience within the range £720-£960 p.a. Voluntary contributory superannuation scheme. A house will be available within a reasonable period for the successful candidate, if married. Application to Ministry of Supply, D.At.En.(P), Risley, Nr. Warrington, Lancs, stating post applied for. W 2107

ENGINEERS AND PHYSICISTS are invited by the Ministry of Supply to apply for vacancies in the Experimental Officer Class at the Royal Aircraft Establishment, Farnborough, Hants, and an outstation in Bucks. For some posts candidates must be capable of development of electronic techniques and equipment. Special experience of miniaturisation, or V.H.F. and U.H.F. radio and radar techniques would be an advantage (D396/51A). Other posts require experience in light mechanical and electrical mechanisms and equipment and candidates should be capable of research and development work in one of the following fields: Electronics, Aircraft instrumentation, Servo mechanisms, Analogue computing and automatic pilots. (D397/51A.) Acceptable minimum qualifications include Higher School Certificate with credit in science or engineering subjects or Higher National Certificate but possession of a Degree in physics or electrical engineering would be an advantage for many of the posts. Salary will be determined on age and on an assessment of the successful candidates' qualifications and experience within the ranges: Senior Experimental Officer (minimum age 35), £742-£960. Experimental Officer (minimum age 28), £545-£695. Assistant Experimental Officer, £240 (age 18)-£505. Rates for women somewhat lower. The posts are unestablished. Application forms obtainable from Technical and Scientific Register (K), York House, Kingsway, W.C.2, quoting appropriate reference. W 2125

£50 A YEAR TAX FREE is bounty paid to electronic artificers joining special section of the Supplementary Reserve. Men with City and Guilds Final Certificate in Telecommunications and Radio and up-to-date experience in current electronic engineering practice will be needed to maintain electronic instruments controlling fire of anti-aircraft guns which protect vital centres of Great Britain should war break out. By joining the SR a man will not only be playing a vital part in the defence of this country but will also know his exact role in the event of war. Minimum rank Staff Sergeant. Minimum of 15 days' training per year with Regular Army rates of pay in addition to the bounty. Further

OFFICIAL APPOINTMENTS (Cont'd.)

details from DDME, A.A. Command, "Glenthorn", Stanmore, Middlesex, or the War Office (AG.10), Department D, London, S.W.1. W 2133

HOME OFFICE: WIRELESS SERVICE. The Civil Service Commissioners invite applications from men with a sound theoretical and practical knowledge of wireless engineering, and experience in the construction and maintenance of Wireless communication equipment, including Very High Frequency apparatus, for the following permanent appointments in the Home Office Wireless Service: (i) 2 posts of Chief Wireless Technician at Headquarters (1 at Northwood Hills, Middlesex and 1 at Whitehall). Candidates must have been born on or before 1st July, 1921, and must have held a senior technical or engineering post in a wireless station, workshop, laboratory or similar establishment. Possession of a City and Guilds Certificate in Radio-communication Grade II or Radio II will be an advantage. Salary (under review), £450-£600 (London); £420-£570 (Provinces). (ii) 4 posts of Senior Wireless Technician at Headquarters at Northwood Hills and 4 in the Regional Wireless Service. Candidates must have been born on or before 1st July, 1926, and must have had at least three years' practical experience, including experience of supervising and directing general wireless installation and repair work. Possession of a City and Guilds Certificate in Radio-communication Grade I or Radio I will be an advantage. Salary (under review) £400-£505 (London); £375-£475 (Provinces). (iii) 10 posts of Wireless Technician at Headquarters at Northwood Hills, and 23 posts in the Provinces. Candidates must have been born on or before 1st July, 1931. Salary (under review) according to age up to 28—£300 (at age 25) to £400 (London); £280 (at age 25) to £370 in the provinces. Further particulars and application forms from Secretary, Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S 4074/51. Completed application forms must be returned by 25th October, 1951. W 2148

PERSONNEL experienced in the maintenance and repair of electronic control and radar equipment are required for civilian appointments in North West, Midlands and South Wales. Salary £435-20 to £550 for Technical Assistants Grade III with opportunities for promotion to higher grades. Married accommodation may become available for selected personnel. Vacancies exist also for telecommunication and radar mechanics with general experience at £6 16s. 0d. per week. Training facilities available. Form of application from A.D.M.E. 4 A.A. Group, Peninsular Barracks, Warrington, Lancs. W 2153

PROFESSIONAL ENGINEERS in Government Departments. The Civil Service Commissioners announce an Open Competition to be held during 1951, for permanent appointments in many Departments of the Civil Service for a wide variety of engineering duties. Applications will be accepted at any time but not later than 31st December, 1951, and selected candidates will be interviewed as soon as possible, after the receipt of their Application Forms. Candidates are advised to apply as early as possible. Age limits: Candidates must be under 35 on 30th November, 1951, with extension for regular service in H.M. Forces and for established Civil Service. For appointments in the Post Office they must be 21 or over, in the Ministry of Supply, 23, and in all other Departments 25 or over on that date. Minimum Qualifications vary for different posts. Generally a University Degree in Engineering or Corporate Membership of the Institutions of Mechanical Engineers, Electrical Engineers or Civil Engineers, or passes in or exemption from Sections A and B of the corresponding Associated Membership examinations, or evidence of exceptionally high professional attainment are required. For certain posts, Corporate Membership of the Institute of Fuel by examination or the Institution of Chemical Engineers, or Graduate Membership of the Institution of Chemical Engineers, or Associate Fellowship of the Royal Aeronautical Society or an Honours Degree in Physics will be accepted instead. The salary on appointment will be fixed according to age. The salary for men aged 26 in London is £500 rising by annual increments of £25 to £750. Salaries for women and for posts outside London are lower. There are prospects of promotion to higher grades on scales for men in London of £750-£1,000, £1,050-£1,270 and above. These rates are at present under review. Further particulars and applications forms from Secretary, Civil Service Commission, Trinidad House, Old Burlington Street, London, W.1, quoting No. S85/51. W 2112

RADAR AND ELECTRONIC technicians are required for repair and maintenance of Radar and Electronic control and computing equipment in the Glasgow and Edinburgh areas. Applicants should have had experience comparable with the standard of Armament Artificer (R.E.M.E.) or hold National Certificate in Electrical Engineering or equivalent qualifications. Salary in scale £437 (at 26) by £20 to £545. Applications should be addressed to A.D.M.E. 3.A.A. Group, Riccarton House, Currie, Midlothian, giving details of experience, qualifications and age. W 2134

TECHNICAL AUTHORS, required for Ministry of Supply Establishments at Chessington, Malvern and Farnborough. Qualifications: British of British parentage; Engineering apprenticeship and either a Degree in engineering or physics or be corporate member of one of the Institutions of Electrical, Mechanical or Civil Engineers or possess exempting qualifications; alternatively candidates with good practical experience in a responsible technical position, preferably holding a National certificate or equivalent will be considered. Must have had either research or development experience of the apparatus and techniques in industry or the Services on the operation and servicing of equipments described below. Experience in writing or editing technical publications an advantage. Duties: Preparation of official instructional publications on the theoretical and practical (including servicing) aspects of airborne and ground centrimetric radar or radio communications equipment. Salary: £330/£570-£720 p.a. not established. Application on forms from Ministry of Labour and National Service, Technical & Scientific Register (K), York House, Kingsway, W.C.2, quoting D.375/51A. Closing date 29th September, 1951. W 2105

TECHNICAL AUTHORS required for Ministry of Supply Establishment at Chessington. Duties involve the preparation of official instructional publications and vacancies exist in the following groups: (A) D.376/51A. Handbooks and circuit diagrams on the theoretical and practical (including servicing) aspects of airborne and ground electrical and electronic equipment, or on complete installations in aircraft. (B) D378/51A. Instructional publications on the theoretical and practical (including servicing) aspects of aircraft gun sights, bomb and torpedo sights, or complex types of aircraft navigation and computing instruments, including gyroscopes and optical systems and the application of electronics. (C) D377/51A. Instruction publications embracing aircraft and associated airborne and ground equipment, including airframes, electrical components and installation, air armaments, mechanical transport and airfield construction plant. Qualifications: British of British parentage; engineering apprenticeship or equivalent training with extensive experience in a responsible technical position in industry or the Services on one group of the equipments mentioned above. Experience in writing or editing technical publications and possession of a National Certificate in mechanical or electrical engineering or equivalent qualifications advantageous. Salary: According to qualifications and experience in the range £540-£785 not established. Application on forms from Ministry of Labour and National Service, Technical & Scientific Register (K), York House, Kingsway, W.C.2, quoting appropriate reference No. W 2106

SITUATIONS VACANT

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

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

A NUMBER of vacancies exist for Electro-Mechanical Designers with a good Degree in mechanical and electrical engineering, or similar qualification, and several years' experience in a Laboratory or Factory design department. Successful candidates will be expected to work in laboratory teams or in laboratory factory teams on interesting and varied projects, and to be responsible for the mechanical design of equipment. The posts are permanent and pensionable. Salary according to qualifications and experience and consistent with present day levels. Application form from Personnel Officer, Mullard Research Laboratory, Cross Oak Lane, Salfords, near Redhill, Surrey. W 2116

APPLICATIONS ARE INVITED for the responsible position of flight engineer for Guided Missiles. Applicant should be of Degree standard and have practical experience of mechanical and electrical installation. Knowledge of telemetry and servo mechanisms is desirable, though not essential. North London district. Write full details, qualifications, experience, age, salary sought to Box A.C. 65692 Samson Clarks, 57-61 Mortimer Street, W.1. W 2155

A VACANCY exists in the Electronics Section of the Research Department for an Electronics Engineer, preferably with a Degree in mathematics, for the design of equipment for electronic measurement of physical variables and associated problems. Applications, stating age, qualifications, experience and salary required, should be addressed to the Personnel Officer, Westland Aircraft, Limited, Yeovil, Somerset. W 1338

A VACANCY EXISTS for a Senior Wireless Engineer to control a team engaged on research, development and engineering of new low power equipments in the 400-600 megacycle band. Salaries up to £1,200 per annum offered to suitable candidates. Please write giving full details and quoting Ref. H.H.E. to Box No. W 2144.

A WELL KNOWN COMPANY undertaking interesting radar development work in the London area has vacancies for the following: 1. Senior Electronic Engineer who must be fully experienced in the design of radar equipment. Degree desirable, salary about £800 p.a. (Ref. IBA.) 2. Mechanical Engineer conversant with Naval radar installation and control systems. Degree desirable, salary according to qualifications and experience. (Ref. IBB.) 3. Designer Draughtsmen, H.N.C. desirable, should be capable of working on own initiative and doing all necessary calculations and Draughtsmen with general electronic and/or mechanical experience. Salary according to qualifications and experience. (Ref. AEF.) Applicants should write quoting appropriate reference to Box No. W 2079.

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

BOULTON PAUL AIRCRAFT LTD., have several interesting vacancies for Electronic Engineers, Test Assistants, Wireman, etc. Development and project experience especially in the instrumentation field an advantage. Write in first instance stating qualifications, age and experience to: The Personnel Manager, Boulton Paul Aircraft Ltd., Pendeford, Wolverhampton. W 1340

CINEMA-TELEVISION LIMITED, have the following vacancies—Senior Assistant Engineers. Applicants should possess H.N.C. or equivalent, and have not less than 4 years' practical experience in the design of television camera equipment and like apparatus. Successful candidates will be required to accept responsibility for the development and design of such pro-

CLASSIFIED ANNOUNCEMENTS
continued on page 4

jects. Junior Assistant Engineers. H.N.C. Standard, preferably with practical experience in the design and construction of electronic test apparatus. Senior Development Engineers. B.Sc. Standard. 5 years' or more experience in the design of electronic test apparatus. Candidates will be responsible for the development and design of such products. Senior Engineers with Degree, preferably in Maths. or Maths./Physics, to be engaged on development work on Telecommunications and Test equipment. Must have sound fundamental knowledge of electrical theory. Five-day, 39-hour week. Good canteen facilities. Pension scheme. Write, stating age, experience and salary required to Cinema-Television Limited, Worsley Bridge Road, Lower Sydenham. S.E.26. W 2129

ELECTRONICS ENGINEER required for development of special purpose electronic devices for use in a manufacturing concern. The main requirements are a good knowledge of circuits employing valves and photocells and ability to devise circuits to suit particular purposes. Reply stating age, technical training, experience and salary required. Brentford district. To Box No. W 2114.

ELECTRO-HYDRAULICS, LIMITED require a Chief Electrical Engineer to be responsible for the design and development of light electrical equipment for aircraft and other purposes. Applicants should have a first or second class Honours Degree, have served an apprenticeship, or had similar practical training and have had some experience of the control of design and development groups. Knowledge of servo systems and aircraft control gear would be an advantage. Apply: Chief Designer, Electro-Hydraulics, Limited, Warrington. W 1342

ENGLISH ELECTRIC CO. LTD., have vacancies for Senior and Junior Electro-Mechanical Engineers for interesting work on long term project. Location Bedfordshire. A Degree or equivalent in electrical engineering or physics essential. Experience in one or more of the following fields desirable: (i) Servo-mechanisms. (ii) Instrumentation. (iii) Electro-mechanical Design. (iv) Vibrations. (v) Electronics. (vi) Electro-mechanical or electronic computing. Salary scale—Senior Engineers up to £1,200—Junior Engineers up to £600. Applicants should write giving full details and quoting ref. 254A to Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, Westminster, S.W.1. W 2127

ENGLISH ELECTRIC VALVE CO. LIMITED, Chelmsford, require a young engineer for testing and development work on Microwave Klystrons. Suitably experienced and qualified applicants should write giving full details and quoting reference 419B to Central Personnel Services, English Electric Co. Limited, 24-30 Gillingham Street, London, S.W.1. W 2151

DECCA RADAR LIMITED, have established themselves in a position of pre-eminence in the field of marine radar. New programmes of research and development are proceeding on projects of outstanding interest and importance, for which well equipped laboratories have been acquired at Tolworth, Surrey, and vacancies exist for senior and junior physicists, engineers and mechanical designers with experience in centimetric radar, display systems and associated electronic equipment. The vacancies to be filled will appeal to ambitious men who wish to join a young progressive company where ability, initiative and hard work will be recognised and rewarded. All those with suitable qualifications who wish to be considered for the positions available are invited to write in confidence to the Managing Director, Ref. T, Decca Radar Limited, 1-3 Brixton Road, London, S.W.9. W 2157

DEVELOPMENT ENGINEERS, Senior and Junior, are required for interesting development work in connexion with airborne Servo-mechanisms and allied control devices. The work involves the study of low frequency electrical and electro-mechanical systems including relays, motors, transductors and electronic circuits at the highest possible standards. Men with a good general physical background are required in addition to those with experience in the fields indicated. Long term projects are available and pensions scheme for Senior Engineers. Please write fully, in confidence, stating salary desired to Box No. W 2141.

DRAUGHTSMAN required with light precision mechanical experience and electrical knowledge capable of design work on electro-mechanical equipment for sound recording and reproduction. Pension scheme. London area. State age, technical training, and full details of experience also salary required. Box No. W 2138

DRAUGHTSMEN are invited to make an appointment with E.M.I. Engineering Development, Limited, to discuss the several vacancies available at their Hayes and Feltham branches. All grades of designers and draughtsmen are required for a wide range of engineering products for which their experience may be suited. Details will be sent by post on request, and/or strictly confidential interviews arranged without obligation. Posts available offer a maximum of interest, technical information and experimental facilities, and long term employment prospects with good salary to suitable applicants. Apply, giving fullest details of experience, qualifications, etc., to Personnel Department EB/A, E.M.I. Engineering Development Limited, Hayes, Middlesex. W 2071

E. K. COLE, LIMITED, have vacancies for testers at their Electronics Division. Experience in the testing of Radar, Communications or Electronics equipments to Ministry specifications, essential. Full details in writing to the Personnel Manager, Malmesbury, Wilts. W 2091

ELECTRICAL DESIGNER required to take charge of experimental work on industrial measuring and control instruments with particular experience in relay design, for progressive factory in North West London area. Sales experience desirable. Send full information in chronological order together with salary required, to Box No. W 2142.

EXPERIENCED Electronic Wiremen required immediately for top priority Government Contracts. Excellent wages, working conditions and prospects for the right type of applicant. Apply: Peto Scott Electrical Instruments, Addlestone Road, Weybridge, Surrey. W 2058

ELECTRO-MECHANICAL ENGINEERS with good academic qualifications, apprenticeship, theoretical background and knowledge of production methods, required for development work. Experience in electrical methods of computation, servo theory and instrument design desirable. Apply with full details of age, experience and salary required to the Personnel Manager, Sperry Gyroscope Company Limited, Great West Road, Brentford. Middlesex. W 2102

ELECTRONIC ENGINEERS with good academic qualifications and apprenticeship required for development work. Experience in one or more of the following desirable: Control systems, D.C. Amplifiers, computing devices, video circuits, microwave techniques. Apply with full details of age, experience and salary required to the Personnel Manager, Sperry Gyroscope Company Limited, Great West Road, Brentford, Middlesex. W 2101

ELECTRONIC ENGINEERS required for interesting development work in a steadily expanding Company in the West London area, specializing in light electrical products. Candidates must have Degree or equivalent qualifications and some years laboratory experience on design of radar or similar equipment. Starting salary in range £750-£1,000, according to experience, with excellent prospects for men of ability and initiative. Applicants should write giving full details of qualifications and experience to Box No. W 2118.

ELECTRONIC ENGINEER required to join a team of research workers investigating a new field in the use of electronic equipment. Qualifications include an Honours Degree in Physics or Engineering which, if in the computing and pulse circuit fields, would be considered an asset. Salary would be according to qualifications and experience, ranging up to £1,000 per annum. Contributory pension scheme. Box No. W 2100.

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 specialized experience in the following fields: (a) L.F. Equipment. (b) Television Equipment. (c) Microwave Techniques. (d) Pulse Techniques. (e) Servo Mechanisms. (f) Test Gear Designs. (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., Hayes, Middlesex. W 2120

ENGINEER for transformer design work, used to small power audio and pulse transformer work, required by prominent aircraft firm in the London area. Highest technical ability and experience of miniaturisation required. Write full details, qualifications, experience, age, salary sought to Box AC 64420, Samson Clarks, 57/61 Mortimer Street, W.1. W 2045

ENGINEERS REQUIRED for interesting work in a steadily expanding Company in West London area, engaged on the development of electronic equipment primarily for the development of radio transformers and similar components. The work involves investigation of the application of new magnetic materials to transformer design. Applicants should write, giving full details of qualifications, experience and salary required to Box No. W 2126.

EXPERIMENTAL ASSISTANT required for work in connexion with the instrumentation of experimental coal burning equipment. Previous experience with electrical recorders, pyrometry and gas flow measurement would be an advantage, but is not essential provided the candidate has ability in light engineering fitting and a keen interest in practical scientific work. Matriculation or ordinary National Certificate standard essential. Salary range £420-£520. Superannuation Scheme. 5-day week. Apply in writing to the Assistant Secretary, Ref. A.18, B.C.U.R.A., Randalls Road, Leatherhead, Surrey. W 1351

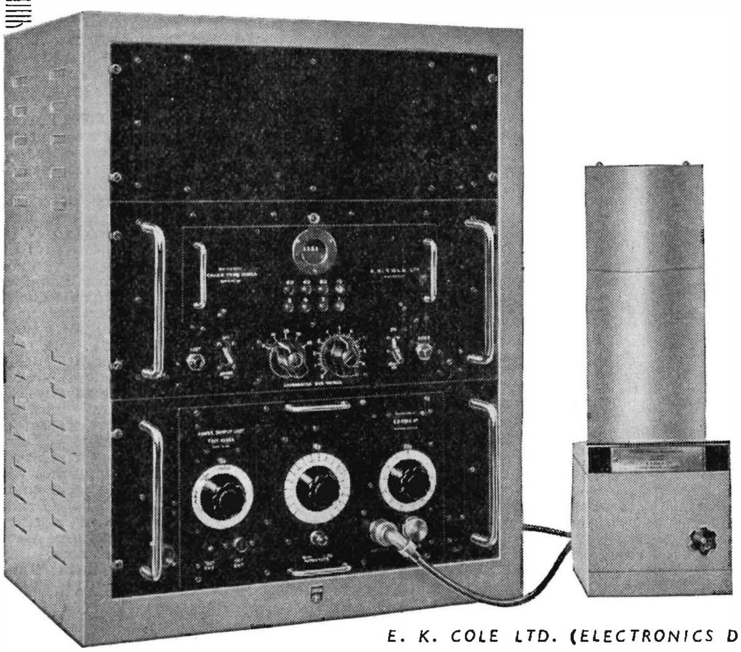
EXPERIENCED ENGINEERS required to fill the following vacancies in the Electronics Laboratories of a Company situated near London. 1. Deputy Section Leader of Microwave and R.F. Laboratory. Applicants should hold an Honours Degree or equivalent in either Physics or Maths plus some industrial experience. 2. Deputy Section Leader of Circuits Laboratory. Applicants should hold an Honours Degree or equivalent and have extensive experience of Electronics generally and Pulse techniques in particular. 3. Designer Draughtsmen to work on light mechanical devices, associated with electronics generally. Applicants should hold a Higher National Certificate or equivalent, preferably in Mechanical Engineering. These posts qualify for the company's pension scheme. The work is both novel and interesting and involves the development of new techniques but not original research. Successful applicants will, after a probationary period, be expected to carry the full design responsibility of a particular project. Apply giving details of age, experience and salary required to Box No. W 2130.

FERRANTI, LIMITED have vacancies for Engineers with experience or interest in work connected with Electro-Mechanical Gunnery Predictors, Gyroscopic Instruments and Allied Projects. Preference given to holders of degrees or equivalent qualifications, but aptitude and practical ability in light mechanical or electrical engineering is essential. Salary according to age and experience in the range of £350-£650 per annum. The company has a Staff Pension Scheme. Forms of application from Mr. R. J. Hebbert, Staff Manager, Ferranti, Limited, Hollinwood, Lancs. Please quote Ref. E.E.M. W 2049

FERRANTI LTD., Moston Works, Manchester, have staff vacancies in connexion with long term Development Work on an important Radio Tele-Control Project. (1) Senior Engineers or Scientists to take charge of research and development sections. Qualifications include a good degree in Physics or Electrical Engineering and extensive past experience in charge of development work. Salary according to qualifications and experience in the range of £1,000-£1,500 per annum. Please quote reference R.S.E. (II) Engineers and Scientists for research and development work in the following fields: Radar, radio and electronic circuits, micro waves, high power centrimetric valves, vacuum and/or high voltage techniques, servo control and electro-mechanical devices. Qualifications include a good degree in Physics or Electrical Engineering or Mechanical Science, or equivalent qualifications. Previous experience is an advantage but is not essential. Salary according to qualifications and experience in

CLASSIFIED ANNOUNCEMENTS
continued on page 6

EKCO SCINTILLATION COUNTER TYPE N502

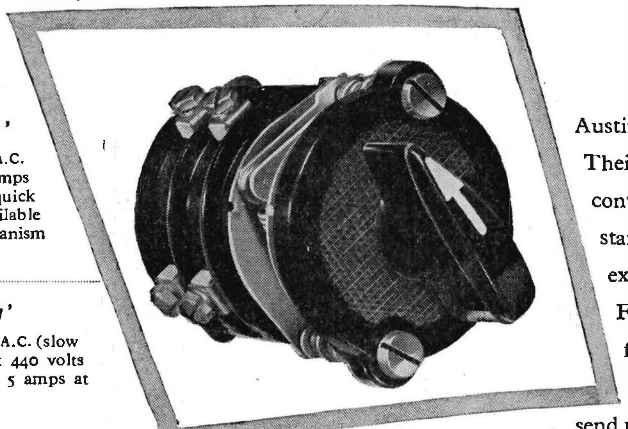


For the first time in this country EKCO make available a self-contained Scintillation Counter for the accurate measurement of Alpha and Beta particles and Gamma rays. A high-gain, low dark-current photo-multiplier tube, in a lead castle giving adequate shielding, is combined with a wide band fed-back linear amplifier thereby providing a self-contained unit suitable for use with an Ekco Scaler 1009A, a Ratemeter 1037A or other suitable counting equipment. In general, counting may be accomplished at higher rates and with much greater efficiency than with the conventional G.M. counter.

Full details of this and other Ekco equipment for the Radiochemical Laboratory will be sent on request

EKCO
ELECTRONICS

E. K. COLE LTD. (ELECTRONICS DIVISION) 5 VIGO STREET, LONDON, W.1



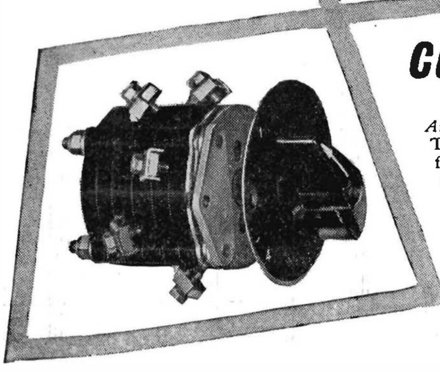
Austinlite 'Fifty'

50 amps at 450 volts A.C. (slow break). 20 amps at 250 volts D.C. (quick break). Also available with 6 or 8-way mechanism for tapping etc.

Austinlite 'Thirty'

30 amps at 250 volts A.C. (slow break). 15 amps at 440 volts A.C. (slow break). 5 amps at 230 volts D.C.

Austinlite switches are built for heavy duty. Their intelligent use for all forms of motor control including reversing, star delta starting and dynamic braking can save the expense of separate contactors or relays. For heater selection, on load transformer tap changing, or change-over switching, they are unrivalled. Why not send us details of *your* switching problem ?



Cut your control gear costs

Austinlite switches are used and specified by : The Admiralty ; British Electricity Authority ; The Air Ministry ; British Broadcasting Corporation ; General Post Office ; Crown Agents for the Colonies ; National Physical Laboratory ; Royal National Lifeboat Institution and most of the leading electrical manufacturers in Great Britain.

A *Chance* PRODUCT

AUSTINLITE LIMITED *(A subsidiary of Chance Brothers Limited)*
Dept. A.5, Lighthouse Works, Smethwick 40, Birmingham. Tel: West Bromwich 1824

the range £420-£1,000 per annum. Please quote reference R.T.E. (III) Technical Assistants for experimental work in the fields listed in (II) above. Qualifications required: a Degree or Higher National Certificate in Electrical or Mechanical Engineering or equivalent qualifications. Salary in the range of £260-£550, according to age and experience. Please quote reference R.T.A. The Company has a Staff Pension scheme, and will give housing assistance in special cases. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti Limited, Hollinwood, Lancs. W 2970

FERRANTI, LIMITED, Moston Works, Manchester, have staff vacancies in connexion with special electronic valve development and manufacture in association with an important Radio Tele-Control project. (1) Senior Valve Engineers to take charge of Research and development work. Qualifications include a good Degree in Physics or Electrical Engineering and extensive experience in charge of development work. Salary according to qualifications and experience in the range of £1,100-£1,600 per annum. Please quote Ref. S.V.E. The company has a Staff Pension Scheme, and will give housing assistance in special cases. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti, Limited, Hollinwood, Lancs. W 2044

FURZEHILL LABORATORIES LTD., Boreham Wood, Herts., have vacancies for Electronic Engineers. Applications are invited for the Cheltenham Laboratory which is engaged mainly on the development of servo systems for aircraft and industrial purposes and for the Boreham Wood Laboratory handling Laboratory Measuring Instruments. Posts are available for Project Engineers who should preferably hold an Honours Degree, Development Engineers of Degree standard, Junior Engineers and Design Draughtsmen. Salaries range from £350 to £1,200 p.a., and houses are available to selected applicants in the Cheltenham area. W 2152

INSTRUMENT TECHNICIANS required to assist with development work in connection with industrial instrumentation. Apply Cambridge Instrument Co. Ltd., Sydney Road, Muswell Hill, N.10. W 2122

JUNIOR DEVELOPMENT ENGINEERS required by Telecommunications Engineers for work on Crystals, Crystal Oscillators and Measuring Gear. Candidates should have good academic qualifications in electrical engineering or physics. Previous experience not essential. Apply Personnel Department, Standard Telephones & Cables Ltd., North Woolwich, E.16. W 2132

JUNIOR ENGINEER required for Acoustics Laboratory of large telephone manufacturing company in S.E. London area, for work mainly on the development of telephone instruments and allied equipment. Degree or H.N.C. essential and preferably some industrial experience in electro-acoustic work. Salary in accordance with experience and qualifications. Write Box No. W 2062.

LABORATORY ASSISTANTS for development on Cathode Ray Photo-Electric and other types of Television Vacuum Tubes. Preference given to applicants with Inter-B.Sc. or equivalent, and with completed National Service. Good Canteen. 5-day week. Pension Scheme. Write, giving age, experience and salary required to Cinema-Television Limited, Worsley Bridge Road, Lower Sydenham, S.E.26. W 2149

LEADING COMPANY requires man to take charge Test Personnel on T/V Transmission and Ancillary Equipment. Write stating age, experience and salary to Box No. W 2128.

LEVER BROTHERS & UNILEVER LTD. require at their Research Laboratories, Port Sunlight, a scientist with a working knowledge of electronics and electrical circuitry. Ability to design and develop electro-mechanical devices is also desirable. Candidates should be under 30 years of age and hold a Degree with honours or equivalent qualifications in physics or electrical engineering. Starting salary will be assessed according to qualifications and experience. Applications should be addressed to: Lever Brothers & Unilever Ltd., Personnel Division (KAB-23) Unilever House, Blackfriars, London, E.C.4. W 2147

LIBRARIAN (Female) required for E.M.I. Technical Library. Qualifications: Good general scientific background with practical experience, preferably in the field of Light Electrical Engineering, coupled with a keen interest in librarianship, though actual experience of this work is not essential. Knowledge of technical German and French would be an advantage. Age over 24 years. Please write, giving full details of experience and salary required, etc., to ED/36, E.M.I. Engineering Development Ltd., Hayes, Middlesex. W 2154

MARCONI'S WIRELESS TELEGRAPH CO. LTD., have the following vacancies in their Television Research Laboratories at Chelmsford. (a) A Senior Television Research Engineer (Ref. 327/1). (b) An experienced Engineer to take charge of a small group engaged in constructing and testing experimental equipment (Ref. 327/3). (c) Technical Assistants for the above group (Ref. 327/4). (d) A junior female assistant for optical and photographic work (Applicants should be of Graduate standard, previous experience desirable but not essential). (Ref. 327/5). These positions offer good salaries, dependent upon experience and qualifications. The Company operates a Pension Scheme. Please apply giving full details and quoting appropriate reference number to Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, London, S.W.1. W 2110

MECHANICAL ENGINEERS required. Good academic qualifications, recognised apprenticeship and some electrical knowledge essential. Experience in one or more of the following desirable: precision mechanical design, fire control mechanisms, servo theory, hydraulic and pneumatic servo systems, aerodynamics. Apply with full details of age, experience and salary required to the Personnel Manager, Sperry Gyroscope Company Limited, Great West Road, Brentford, Middlesex. W 2103

MURPHY RADIO LTD., have vacancies for senior mechanical designers in their electronics division. A full and varied programme ensures opportunity of widening experience with excellent prospects. Application giving particulars of training and experience should be made immediately to Personnel Dept., Murphy Radio Ltd., Welwyn Garden City. W 2131

NORTHUMBERLAND Company manufacturing electronic components requires experienced electronic technician immediately for development and construction, under technical supervision, of specialized electronic equipment for internal laboratory and factory use. Age 24-30 O.N.C. or preferably H.N.C. or equivalent qualifications. Experience of general workshop practice and electronic instruments, including AC and DC amplifiers and bridges, CRO etc. Salary according to age and experience. Apply Box No. W 2163.

OVERSEAS. Design and Production Engineer required to supervise installation of plant, and take full charge of production of electrical power factor Correction Condensers in South Africa. Box No. W 1355.

PHYSICIST with experience in the electronic field required to aid in the direction of a team of research workers investigating a new field in the use of electronic equipment. Only first class men with an Honours Degree in Physics need apply. The salary will be in conformity with the successful applicant's ability and experience, but will not be less than £1,000 per annum. Contributory pension scheme. Box No. W 2099.

PHYSICISTS required for interesting work in the following fields: (1) Application of new materials to electronic engineering. (2) Cathode Ray Tube development. (3) Properties of magnetic materials and applications to magnetic tape recording. (4) Electronic engineering problems, including microwave applications. The posts are for permanent pensionable staff and carry good salary and prospects. Applicants should have a sound theoretical training with a Degree or equivalent and experience in one of these fields, and should write giving full details and quoting ED/35, to Personnel Department, E.M.I. Engineering Development Limited, Hayes, Middlesex. W 2119

PHYSICISTS AND ELECTRONIC ENGINEERS required for laboratory in Northamptonshire to carry out design of radio and electronic components from new ceramic and magnetic materials. Previous experience desirable. Salary £450-£650 according to qualifications and experience. Box No. W 2052.

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

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

RESEARCH AND DEVELOPMENT Engineers are required by British Telecommunications Research, Limited, a company associated with The Automatic Telephone and Electric Co., Limited, and British Insulated Callender's Cables, Limited, for work on long term development projects in the following fields: (a) Wide-band line communication. (b) V.H.F. and U.H.F. radio communication. (c) Electronic Switching and Computing. A number of posts with a salary in the range £500-£1,200 per annum are available for suitably qualified engineers or physicists with experience in any of the above or allied fields. Further posts are available for technical assistants with salary in the range £300-£600 according to qualifications and experience. Applications are also invited from Honours Graduates in physics or electrical engineering who are considering careers in the research and development side of the telecommunications industry. There is a superannuation scheme and the Company works a five-day week. The laboratories which are well equipped are situated in ideal country surroundings within easy reach of London. Applications, which will be treated in strictest confidence, should be made on forms obtainable from the Director of Research, British Telecommunications Research Limited, Taplow Court, Taplow, Bucks. W 2060

ROLLS-ROYCE LIMITED, Derby, have vacancies for Graduates to work on the study of vibration characteristics of Rolls-Royce Gas Turbine and piston type Aero Engines, under laboratory conditions, on the test bed and in flight. Some knowledge of electrical measurements is an advantage but extensive electronic knowledge is not essential. Salary according to age, qualifications and experience. W 2143

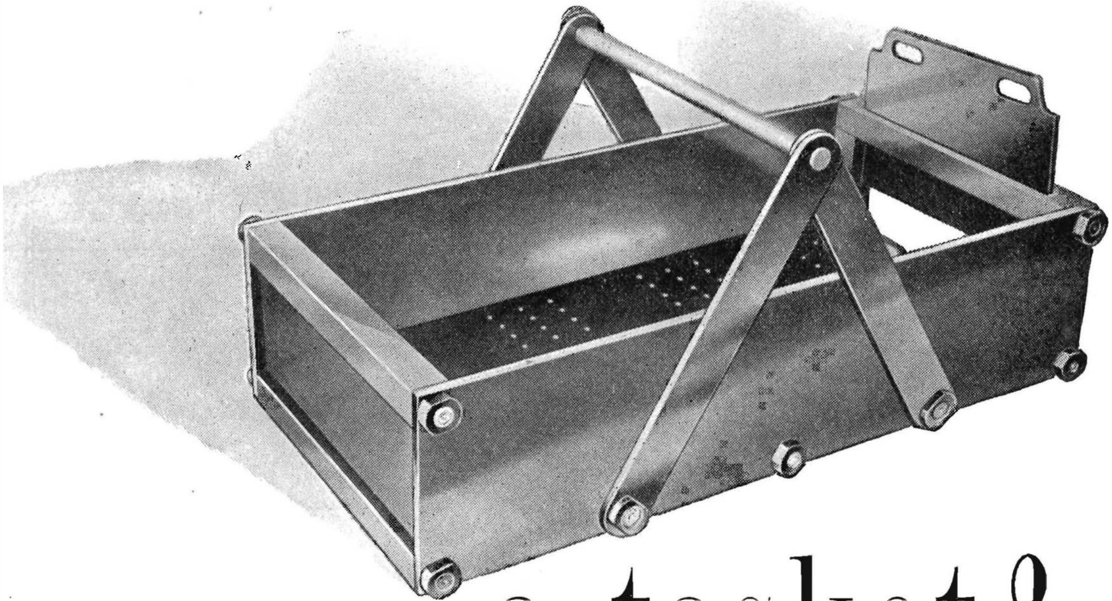
SENIOR DRAUGHTSMEN: Metropolitan-Vickers Electrical Co. Ltd., require for their Trafford Park works, a number of senior draughtsmen preferably with experience in Radio and Radar equipment. For qualified men these jobs are permanent, five-day week under good conditions. Apply in writing stating age, experience,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

SEVERAL DRAUGHTSMEN are required for work on electronic engineering projects. Some of the vacancies are for senior men of at least HNC standard who have spent a number of years in a Laboratory or Factory design department and are capable of original layout work. Other posts are for detailing draughtsmen capable of producing Workshop drawings from such layouts. Salaries will be at current levels according to qualifications and experience. Prospects of promotion are good and the posts fall within the Company's Pension Scheme. Application form from the Personnel Officer, Mullard Research Laboratory, Cross Oak Lane, Salfords, near Redhill, Surrey. W 2117

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

CLASSIFIED ANNOUNCEMENTS
continued on page 8

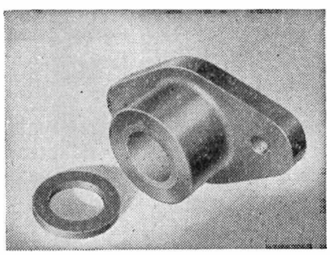
A-tisket?...



a-tasket?...

No! —**A TUFNOL ETCHING BASKET,** quite literally an acid test of Tufnol quality. Yet resistance to corrosion is but one of many virtues which commend this versatile material to an ever-widening circle of users in engineering and industry.

Broadly speaking, when conditions of service expose the limitations of metal or hardwood — there is a case for Tufnol. Structurally strong, light in weight, an excellent electrical insulator, unaffected by moisture or exposure, capable of withstanding extreme climatic conditions — these are physical properties unique in one material.



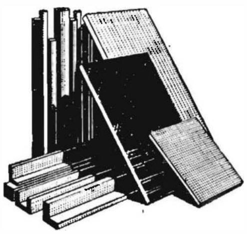
Showing a Tufnol axle bearing and ring used on a coke carrying truck in a gas works.

Tufnol requires no special tooling or skill to transform the raw material into anything from bearings and gears to nuts and bolts. It is supplied in the form of prefabricated components, moulded blanks, or in standard sheets, tubes, rods, bars, angles, channels and other sections.

Tufnol is the material of enterprise and efficiency.

THE STORY OF TUFNOL

is told in our literature. Its physical properties, accurately charted, explain what it is, its many and varied uses prove its worth. Possibly your intended use may add another chapter to the Tufnol Saga — if so you can count on the enthusiastic co-operation of our Technical Staff. Why not write TODAY?



TUFNOL

REGISTERED TRADE MARK

An ELLISON Product

TUFNOL LTD • PERRY BARR • BIRMINGHAM • 22B

247

experience with appropriate dates. Apply Employment Manager, Vickers-Armstrongs Ltd., (Aircraft Section), Weybridge. W 2121

TECHNICAL LABORATORY Assistants with experience in the fields of radio and electronics are required for work in the Stanmore area. Apply in writing giving full details of age, qualifications and experience to the Staff Manager (Ref. GBLC/G/820), Research Laboratories of The General Electric Co. Limited, North Wembley, Middlesex. W 2139

THE BRITISH IRON & STEEL Research Association. Technical Assistant required by the above Association for work in the Instruments Section of their Physics Laboratory in Battersea. Duties will be concerned with the design and development of industrial measuring and control instruments. A National or Higher National Certificate in Electrical Engineering or applied physics. Age range 20-25. Starting salary up to £480 per annum according to age, qualifications, and experience. Written applications only, quoting "Electronics" to Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1. W 2158

THERE ARE a number of vacancies suitable for Honours Graduates in physics, electrical or mechanical engineering or mathematics or a good general Degree covering two or more of these subjects, for both research and development work in the following fields: Radio and Line Communications, Radar, Electronic Instrumentation, Microwaves, Ultrasonics, Vacuum Techniques and Electromechanical Devices. Salary according to qualifications and experience consistent with general present-day levels. These are vacancies for which considerable post-graduate experience is required. Consideration will be given to students taking finals during the current academic year. Prospects of promotion are good and the posts all fall within the Mullard Company's Superannuation Scheme. Apply Personnel Officer, Mullard Electronic Research Laboratory, Salfords, Nr. Redhill, Surrey. W 2896

THE GENERAL ELECTRIC CO., LTD., Radio and Television Works, Coventry, have vacancies for Development Engineers, Senior Development Engineers, Mechanical and Electronic, for their Development Laboratories on commercial and Government work of national importance. Fields include Microwave and Pulse Applications. Salary range £400-£1,250 per annum. Vacancies also exist for Specialist Engineers in Component design, valve applications, electro-mechanical devices and small mechanisms. The Company's Laboratories provide excellent working conditions with Social and Welfare facilities. Superannuation Scheme. Assistance with housing in special cases. Apply by letter stating age and experience to the Personnel Manager (Ref. CHC.) W 2999

THE PLESSEY COMPANY LIMITED, Vicarage Lane, Ilford, have an immediate vacancy for a graduate engineer between the ages of 25 and 35 with an interest in light electro-mechanical devices and another for an electronic circuit designer. Applicants must be British born, and should preferably have had some experience in design work in these fields. The posts are progressive and pensionable, and are in a newly formed division of the Company. Salaries will be in accordance with age and experience. Application should be made, in writing, to the Personnel Manager, quoting reference G.C. W 2123

TRANSFORMER Designer/Engineer required to take charge of small manufacturing plant in Glasgow area. Full particulars to Box No. W 2150.

ULTRASONICS DEVELOPMENT ENGINEER required to explore a new industrial application of ultrasonic vibrational techniques. Must have previous laboratory experience in similar fields. Interesting permanent post for right man. Location Slough. Box No. W 1350.

VACUUM PHYSICS LABORATORY requires engineers or physicists experienced in development of special valves for radar applications at micro-wave frequencies, particularly magnetrons, TR cells or Klystrons. Openings include senior positions for suitable applicants offering good opportunities for advancement. Apply quoting "VPL" and give full details of training, qualifications and experience, and salary expected, to the Personnel Officer, Ferranti Ltd., Ferry Road, Edinburgh. W 2137

V.H.F. COMMUNICATIONS. Progressive and rapidly expanding London Company has vacancies for an Engineer in Charge (working) and V.H.F. Service Engineers. Technicians wishing to join an organisation offering a sound future in the communications field should apply at once stating full details of past experience, salary required, etc., to Box No. W 2146.

WAYNE KERR require several draughtsmen for design and development work on electronic equipment for the Armed Forces. The work is interesting and offers considerable scope for men with initiative and design ability. The projects at present involved are of high priority and form part of the Defence Programme. Attractive salaries in excess of the revised A.E.S.D. rates will be offered to suitable applicants. Write giving full details of past experience to Wayne Kerr Laboratories Limited, Sycamore Grove, New Malden, Surrey. W 2162

WELL-KNOWN FIRM of Electronics Manufacturers, London area, has vacancies for senior and junior engineers for valve and circuit development. Senior £800/£1,000 per annum. Junior £400/£800 per annum according to qualifications and experience. Apply Box No. W 2113.

SITUATIONS WANTED

SENIOR E.E.G. technician 5 years' clinical and research experience, previously 9 years' electronics in Hospital and Forces. West Country preferred. Box No. W 1354.

TRAINING OFFICER (ELECTRONICS), A.M.I.E.E., etc. Experienced power, radio television, writing, design, initiating and conducting training schemes. Desires responsible post. Box No. W 1353.

WANTED

REQUIRED the following Bendix Equipment—BC 640A VHF Transmitter, BS 639A VHF Receiver, RA 42A Power Pack. Must be in perfect condition. Price and details to Box No. 8394 c/o Whites Ltd., 72 Fleet Street, E.C.4. W 2108

FOR SALE

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

ELECTRIC BULBS and lamps for all purposes; neon and discharge lamps; U.S. radio accessories, switches, (Ceramic) condensers, etc. Telephone headsets, breast and headsets, lamps, lamp caps, jacks, plugs, Fullerphones, etc. Suplex Lamps Limited, 239 High Holborn, London, W.C.1. W 1344

GLASS-TO-METAL SEALS and High Vacuum by Hall, Drysdale & Co. Ltd., of 58 Commerce Road, Wood Green, London, N.22. 'Phone: BOWes Park 7221. W 117

INDICATOR UNITS Type 6 and 6a £3 each, carriage paid. 12 Volt 40. A.H. Batteries £3 5s. each carriage paid. Type 1 225 units complete with 5. EF.50, 2. EF.39 Valves 36s. 6d. each, carriage paid. Valves: EF.54. EF.50. EF.36. EF.39. 5s. each. SP.61. SP.41. VR.78. EA.50. VR.18. VR.21. 2s. 6d. each. Carriage extra on valves. J. H. Dakin, 13 Church Road, Edgbaston, Birmingham 15. W 1349

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

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

TO MANUFACTURERS, Universities and Teaching Institutions. There is a wide scope for research and development into the use of servo control elements in industry and applied science. We can supply ex stock many types of Magslips, Selsyns and other servo elements, Inductive Potentiometers (Ipots) and Ball and Plate Integrators for electrical computation. We also have available Magslip gears and mountings. All goods are of ex-Government origin but are fully guaranteed by us and are offered for immediate delivery and at a fraction of Manufacturers' list prices. Write for our free brochure "Synchros," and our price list to: Servotronic Sales, Abbey Road, Belvedere, Kent. W 1352

TOROIDAL COILS, manually wound to one per cent. Bel Sound Products Co., Marlborough Yard, Archway, N.19. ARC. 5078. W 139

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

WIREK Model B2 Mark II Recorder for sale with two one-hour, two half-hour and one quarter-hour spools. Still under Maker's Guarantee. Price £55. Box No. W 1357.

WANTED

WANTED 328A and 394A Western Electric Valves—in quantity. Terry, 50 Westcliffe Road, Bournemouth. W 1330

SERVICE

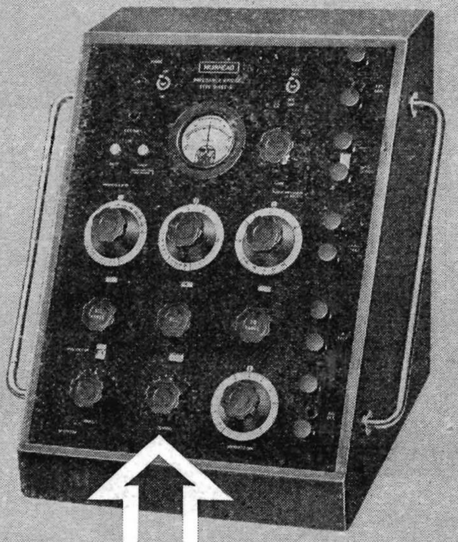
GLASSBLOWING, repetition and scientific, by Hall Drysdale & Co. Ltd., of 58 Commerce Road, Wood Green, London, N.22. Phone BOWes Park 7221-2. W 109

EDUCATIONAL

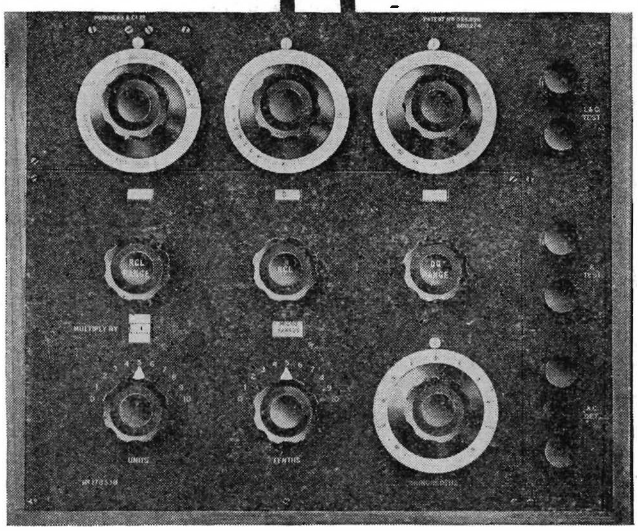
CITY AND GUILDS, (Electrical, etc.) on 'No Pass—No Fee' terms. Over 95 per cent Successes. For full details of modern courses in all branches of Electrical Technology, send for our 144-page handbook—Free and post free. B.I.E.T. (Dept. 337c), 17 Stratford Place, London, W.1. W 123

IMPEDANCE BRIDGE TYPE D-197-A

- Operates from A.C. Mains.
- Built-in 1000 c/s oscillator and amplifier.
- Provision for external oscillator and galvanometer.
- Dual-sensitivity galvanometer key to facilitate final balance.
- Electronic earthing device to reduce zero errors and increase accuracy.
- Better than 1% accuracy over greater part of range.



DIRECT READING IN R, C, L, D AND Q WITHOUT AMBIGUITY



RANGE OF MEASUREMENT

RESISTANCE . . .	0.001 ohm to 1 megohm
CAPACITANCE	1 μμF to 100 μF
DISSIPATION (LOSS) FACTOR . . .	0-1.2
INDUCTANCE	1 μH to 1000 H
MAGNIFICATION FACTOR (Q) . . .	0-60

42k

Please send me Bulletin B-642 describing the Impedance Bridge advertised in "Electronic Engineering."

NAME ______________________

ADDRESS ______________________

MUIRHEAD *PRECISION ELECTRICAL INSTRUMENTS*

MUIRHEAD & CO. LTD.

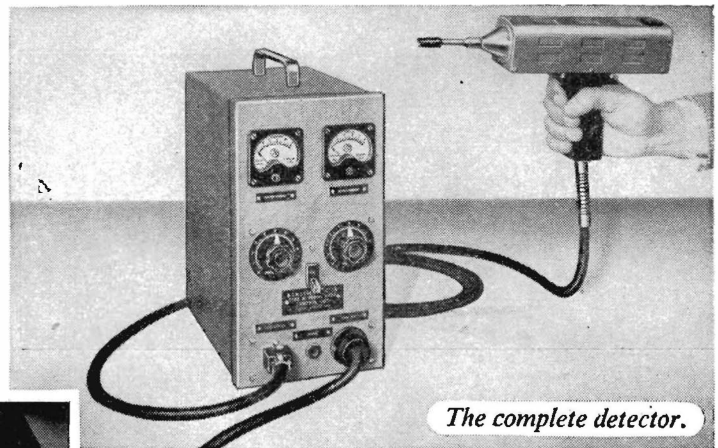
BECKENHAM • KENT • ENGLAND

Telephone: BECkenham 0041
Telegrams and Cables: MUIRHEADS ELMERS-END

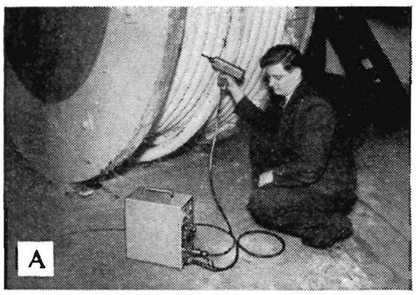
B

Electronic LEAK DETECTOR

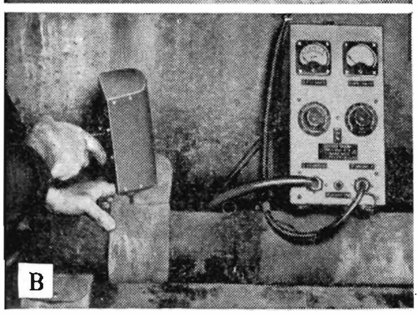
Convenient
Accurate
Sensitive



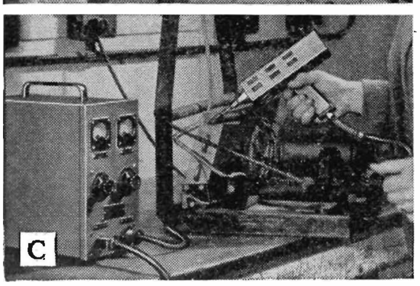
The complete detector.



A



B



C

Leaks in containers or pipes imperceptible by other means can be easily and accurately located by the BTH Type H Electronic Leak Detector. This instrument, developed in the BTH Research Laboratories to detect the vapours of halogen compounds in air, is sensitive enough to react to Arcton ($C\ CL_2\ F_2$) escaping from a container at the rate of 1/50 oz. per year. The detector is easily portable—eminently suited to use in the laboratory or on the assembly line, or for service testing in the field. Applications include testing of refrigeration and air-conditioning plant, which already contains a halogen-bearing compound, and leak-testing of tanks, pipes, joints, welds, pneumatic systems, etc. by introducing a suitable " tracer " gas into the system under test. The detector emits, by means of a small built-in sounder, a series of clicks ; a change of frequency denotes the presence of a leak. For work in noisy surroundings headphones are available.

Illustrations show use of the detector in examining for leaks (A) *Gas-filled cables* (B) *Pipe seams* (C) *Refrigerator unit.*

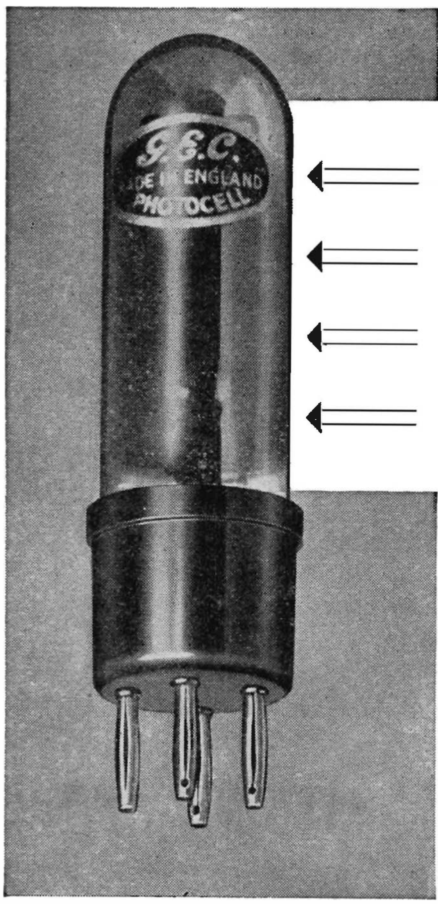
THE
BRITISH THOMSON-HOUSTON
COMPANY LIMITED, RUGBY, ENGLAND

A4293

Member of the AEI group of companies

G.E.C.

Caesium-Antimony Photocells

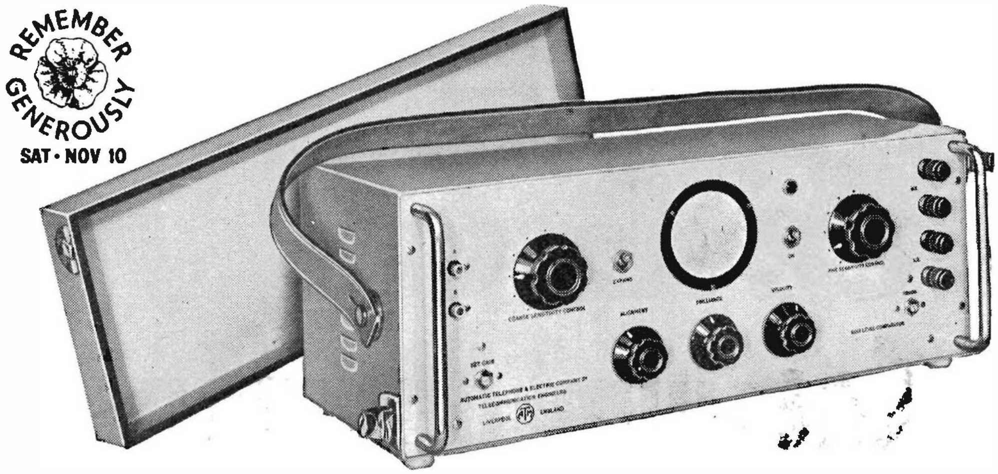


- High sensitivity to artificial light.
- Especially suited to sound reproduction.
- Reduced tendency to microphony.
- Very low noise level.

Gas filled or vacuum.
Dimensions:
92mm seated length,
28mm diameter and
mounted on a four-pin British base.

For further information, write to Osram Valve & Electronics Dept.

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, W.C.2



PRECISION MEASUREMENTS IN LINE TRANSMISSION

In the measurement of losses and gains greater accuracy can be achieved if a visual instead of an audible means is employed. The illustration depicts an electronic voltage comparator in which a cathode ray tube is used as an indicator of the relative magnitudes of a standard signal and the unknown signal to be tested. In the position of maximum sensitivity an input signal of 30 microvolts will give a 1 cm deflection on the screen which allows a comparison accuracy equivalent to 0.1db. Measurements can be made from 100 c/s to 200 Kc/s. This instrument, which is extremely simple to operate, is used as the sensitive detector in the measurement of losses in channelling equipment, amplifier gains, crosstalk and harmonic distortion in amplifiers, etc.

Distributor

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.
(Radio and Transmission Division), Strowger House, Arundel St., London, W.C.2
Telephone: TEMple Bar 9262. Cablegrams: Strowgerex, London.

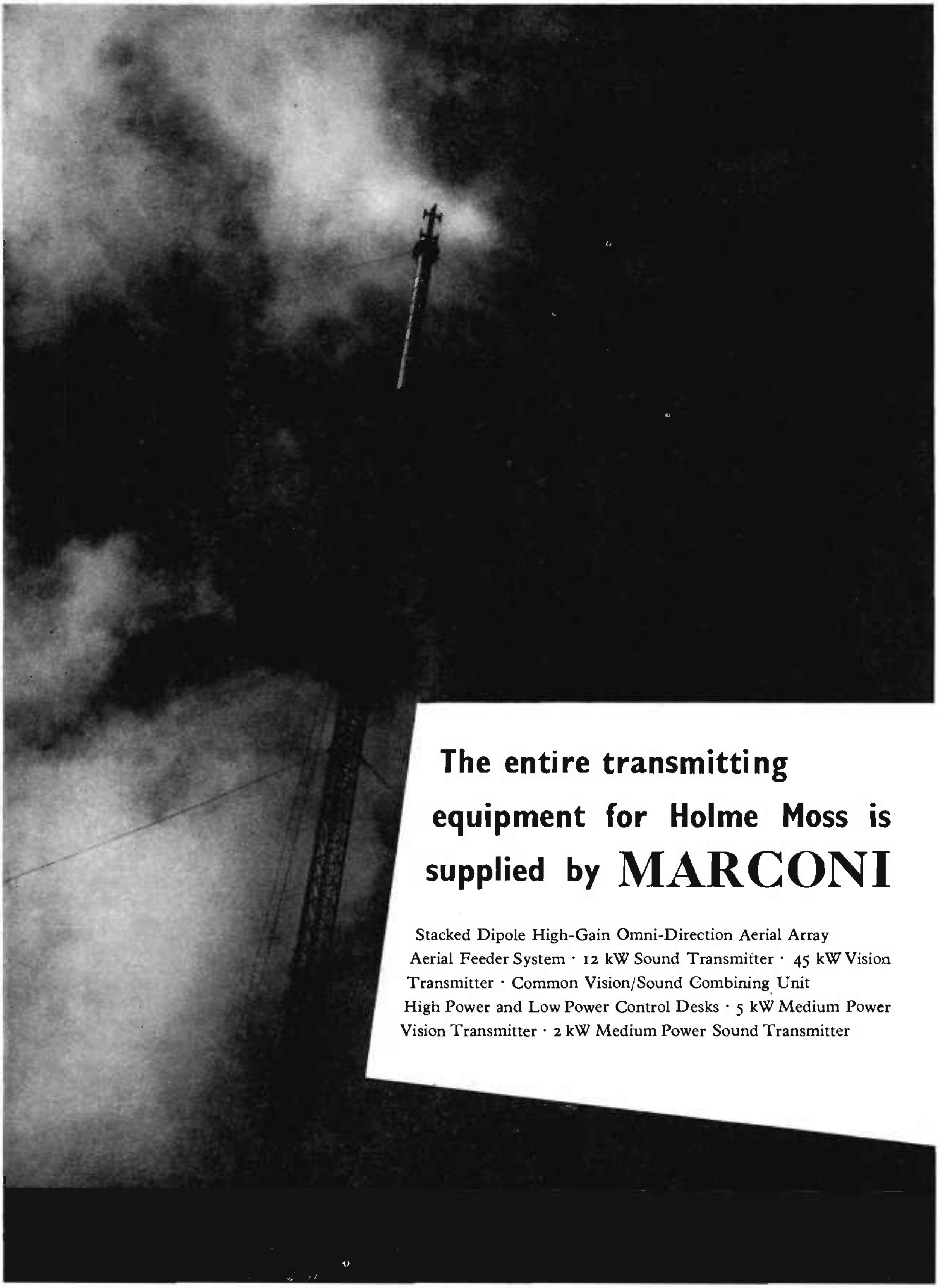
Manufacturers

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD., Liverpool & London
TELEPHONE MANUFACTURING CO. LTD., St. Mary Cray, Kent

ATE/TMC

A8411-B.105


An Announcement . . .
DUREX ABRASIVES LTD. wish to announce that as from June 14th, 1951, the name of the Company has been changed and is now the MINNESOTA MINING & MANUFACTURING COMPANY LTD. Identification will be as before, except that the words " Scotch Boy " will be used instead of " Durex " as a prefix to the name of the material, e.g., " Scotch Boy " Magnetic Recording Tape instead of " Durex " Magnetic Recording Tape.
Existing high standards in the quality of the products will be maintained, the change is in name only.
'SCOTCH BOY'
Magnetic Recording
TAPE
SCOTCH BOY
Magnetic Recording
TAPE
1/4 x 1200 Ft.
DATE
SUBJECT
ANOTHER 3M COMPANY PRODUCT
Manufactured by :—
MINNESOTA MINING & MANUFACTURING COMPANY LTD
167, STRAND, LONDON, W.C.2, and SLOUGH



The entire transmitting equipment for Holme Moss is supplied by MARCONI

Stacked Dipole High-Gain Omni-Direction Aerial Array · Aerial Feeder System · 12 kW Sound Transmitter · 45 kW Vision Transmitter · Common Vision/Sound Combining Unit · High Power and Low Power Control Desks · 5 kW Medium Power Vision Transmitter · 2 kW Medium Power Sound Transmitter

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD · MARCONI HOUSE · CHELMSFORD · ESSEX

The Metrovick
Stabilised D.C. Power Unit

IN laboratories and meter testing stations there is often a demand for a highly stable d.c. voltage supply. The Power Unit, Type **222**, has been produced to satisfy this demand.

SPECIFICATION

Supply: 200/250V, A.C., 50 c/s., single-phase.

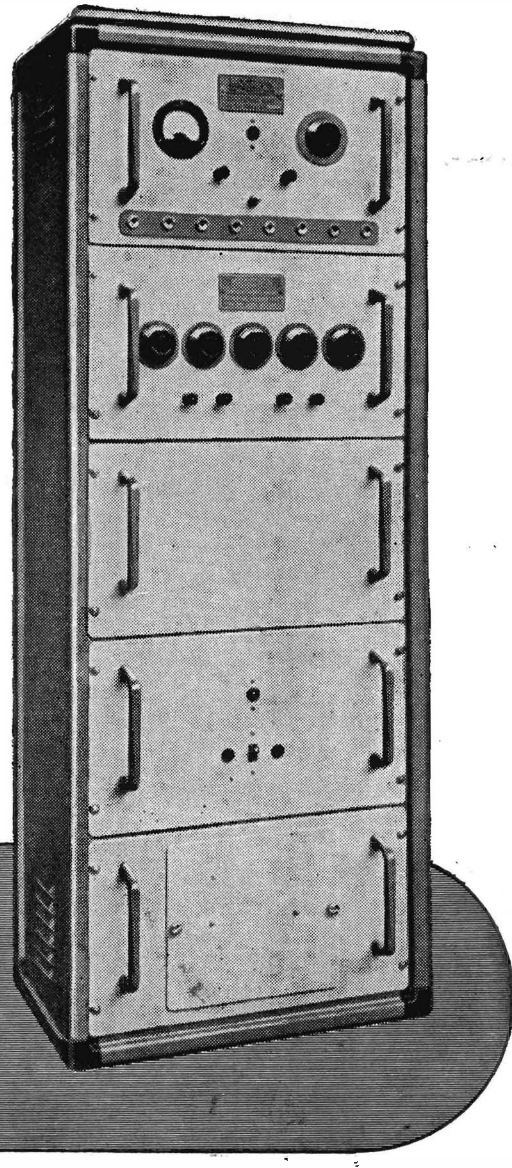
Output: Between 660 and 680 volts D.C. (fixed) at up to 250 mA.

Stability: Maximum drift over 10 min-4 parts in 100,000.
Maximum drift over 1 hr-1·5 parts in 10,000.
These figures apply for mains input changes not exceeding ± 5% after warming up period of two hours.

Output Impedance: Better than 0·1 ohm.

Output Ripple: Approximately 2mV r.m.s.

Stabilised D.C. Power Unit, complete with Voltage Divider Type 292



TYPE 222

METROPOLITAN-VICKERS ELECTRICAL CO. LTD.

TRAFFORD PARK, MANCHESTER 17

Member of the A.E.I. group of companies

K/E 904

complex waveform

with the **Standard**

HIGH FREQUENCY

SPECTROMETER

Display obtained from
16 kc/s square wave shown above.

THIS complex waveform analyser has an exceptionally high resolving speed over a very wide frequency range: 6·4 kc/s to 4·0 Mc/s.

The amplitudes and frequencies of the components of a complex waveform are displayed as a series of vertical lines on the screen of a cathode-ray tube and the instrument is capable of analysing a waveform of a duration of as little as 60 milli-seconds. Photographic records may be made by still or cine camera.

Standard Telephones and Cables Limited

Registered Office: Connaught House, Aldwych, London, W.C.2

TRANSMISSION DIVISION, NORTH WOOLWICH, LONDON, E.16

Electronic Engineering

Incorporating
ELECTRONICS, TELEVISION and SHORT WAVE WORLD

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

Vol. XXIII OCTOBER 1951 No. 284

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 'ELECTRONING, ESTRAND, LONDON'

Subscription Rate:
(Home or Abroad) Post Paid 12 months 26s. or $3.75 **(U.S.)**

Classified Advertisements, Page 1
Index to ADVERTISERS, Page 46

DATA ON THE MT57 TRIODE MERCURY VAPOUR RECTIFIER, ONE OF THE RANGE OF MULLARD THYRATRONS

LIMITING VALUES (ABSOLUTE RATINGS)

Maximum Peak Anode Voltage			
Inverse			1000V *
Forward			1000V
Maximum Cathode Current. 25c/s and above.			
Peak (for general control service)			15A
Peak (for ignitor firing service)			40A
Average (for general control service)			2.5A
Average (for ignitor firing service)			1.0A
Maximum averaging time			15 secs.
Surge (maximum duration 0.1 secs.)			200A
Maximum Grid Voltage.			
Before conduction			-500V
During conduction			-10V
Maximum Grid Current.			
Average (Averaging time 15 secs.)			0.25A
Maximum Grid Resistor			0.1MΩ
Min. Cathode preheating time.			300 secs.
Condensed Mercury Temperature Limits.			40 to 80°C
CHARACTERISTICS.			
Heater Voltage			5.0V
Heater Current			4.5A
Capacitance Anode-grid			4μμF
Deionisation Time (approx.)			1000μ secs.
Ionisation Time (approx.)			10μ secs.
Anode Voltage Drop			16V
Control.			
Anode Voltage	60	100	1000V
Critical grid Voltage (approx.)	0	−1.75	-6.5V
Base 4-pin UX.			

* 1500V for condensed Mercury temperature up to 75°C

THYRATRONS

for fixed and mobile applications

The Mullard range of Thyratrons has now been extended to include types suitable for use in both fixed and mobile equipments.

For fixed power and motor speed control applications, a selection of Mercury Vapour tubes is available providing maximum average anode current ratings from 0.5 to 6.4 amperes.

For relay, switching and motor control applications in aircraft, ships and industry where movement is encountered, a selection of rare-gas-filled tubes is also available. Important among these is a series of xenon-filled tubes with anode current ratings from 0.1 to 6.4 amperes. On account of the small variations-with-temperature of xenon gas, these tubes are ideal for use in equipments operating over a large ambient temperature range.

The Thyratron illustrated and described here is the 2.5 amp. MT57. Full details on the complete range of Mullard Thyratrons will be supplied on request.

Mullard

INDUSTRIAL POWER VALVES · THYRATRONS · INDUSTRIAL RECTIFIERS · PHOTOCELLS FLASH TUBES · ACCELEROMETERS · CATHODE RAY TUBES · STABILISERS AND REFERENCE LEVEL TUBES · COLD CATHODE TUBES · ELECTROMETERS, ETC.

MULLARD LTD., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

MVT96 (REV).

Electronic Engineering

Vol. XXIII. **OCTOBER 1951** No. 284.

Commentary

THE early autumn is usually the time of year set aside for exhibitions and conferences, and the month which has just passed has provided substantial evidence of the varied activities of the electronic engineer. On what might be regarded as the lighter side there was the excellent Model Engineers' Exhibition at Westminster where the high light was working demonstrations of radio controlled model ships and tanks. But these demonstrations should not be set aside as mere frivolities for the amusement of the young adolescent. At the other end of the scale, the Interplanetary Society was learnedly discussing space travel, and while ways and means of projecting craft into outer space remain unsettled it is certain that the electronic engineer will be called in to provide the control and navigational aids. The radio controlled model aircraft of today may well be, in fact, the forerunner of the pilotless rocket ship of tomorrow.

More spectacular, or course, were the displays of full sized aircraft at Farnborough, organized by the Society of British Aircraft Constructors. While the emphasis was undoubtedly on the revolution in flying brought about by the jet engine, here again, the electronic engineer could take comfort in the fact that breathtaking as were the performances of the re-heat Venom and the P1067, the modern high speed machine is quite valueless without the radar and navigational aids which he has developed.

More at ground level, the Engineering and Marine Exhibition at Olympia would have provided him with excellent examples of the manner in which such applications as R.F. heating and Marine Radar are finding their rightful places in the leading engineering exhibition of the world. It is significant that while notices had to be posted at the entrances to Olympia, advising the general public that this exhibition was *not* the Radio Show, there was a very much better display of "Electronics at Work" than at the Radio Show at Earl's Court.

The 1951 Radio Show, or to give it its full title, the Eighteenth National Radio and Television Exhibition, was held this year at Earl's Court instead of its usual home at Olympia. Attendances on the whole were disappointing, being just about half the 1949 Radiolympia figures, and the recent increase in purchase tax on radio and television receivers, our pre-occupation with rearmament and the comparatively early date of the exhibition might well be contributory causes. The Radio Show is designed primarily as a public exhibition and not exclusively as a private trade exhibition, since the general public are the ultimate purchasers. It seems to us that Earl's Court has not caught the magic of Radiolympia and there was little either new or novel to attract the interested listener and viewer. Excellent displays were of course provided by the armed services, but by the very nature of things the latest developments could not be put on view and these exhibits could only be regarded as part of a recruiting campaign.

* * *

A satisfactory response has been obtained from the questionnaire which was inserted in last month's issue of ELECTRONIC ENGINEERING and it is felt that a word or two of explanation on the reasons which have prompted us to make this investigation into our readership would not be out of place.

Unlike proceedings of the learned and professional societies which are despatched direct to members, journals such as ELECTRONIC ENGINEERING are distributed through newsagents, as well as to those readers who subscribe direct. But even in the latter case, names, and particularly private addresses, do not always convey information as to the occupation or interests of the reader.

The time has long passed when "radio engineering" was confined solely to the business of making radio transmitters and receivers, and today the subject of electronics, which has been defined as "That branch of science and technology which relates to the conduction of electricity through gases or in vacuum," covers a very wide field indeed. In order therefore to report more fully progress and development in this new science, it is essential for us to know more about our readership.

The reader may rest assured that the information will be treated confidentially and will be used solely for his ultimate benefit.

A second card is included in this issue for those readers who did not complete the first.

Equipment for Acoustic Measurements

(Part 2)

A Portable Tone Source Developed for Use in Room Acoustics †

By C. G. Mayo, M.A., B.Sc., M.I.E.E., * and D. G. Beadle, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E. *

It is usual when making measurements in room acoustics to use an audio frequency tone warbled to average the reverberation time over a band of frequencies and it is desirable that the bandwidth should be a fixed percentage of the mean frequency. One method of achieving this result is to rock the stator of the variable capacitor of the oscillator circuit by a motor-driven cam, but this method adds considerable weight and bulk to the equipment as well as causing mechanical vibration and consequent microphony in the valves. Various electronic methods of warbling have been tried, but they usually take the form of a reactance valve across the tuned circuit, and unless the gain of the reactance valve is varied in step with the variable capacitance, the bandwidth will be a fixed number of cycles and independent of the mean frequency.

In the instrument to be described an electronic warble having a fixed percentage deviation from the mean frequency has been obtained, and a small synchronous motor and gear box are included to give slow glides. By the use of miniature components the outside dimensions of the tone source have been kept to 17in. × 10in. × 6in. with a total weight of just under 20lb.

The main details of the portable tone source are:

Frequency Range	20-20,000c/s on a single dial with logarithmic divisions. Adjustment of ± 50c/s on an incremental dial.
Accuracy	Resetting accuracy better than 1 per cent, scale length approximately 20in.
Warble Tone	A 10 per cent warble at 7c/s is obtainable at all settings of the dial with negligible amplitude modulation.
Output Level	Either + 20db or 0db above 1 milliwatt into 600 ohms, selected by means of a key and a 25db uncalibrated variable control.
Output Impedance	600 ohms balanced.
Harmonics	0.5 per cent at maximum output of + 20db. (Note: The full output of + 20db is not obtainable below 50c/s owing to limitation on size of output transformer.)
Hum and Noise	More than 55db below maximum output.
Frequency Characteristic	Flat within ± 0.25db from 20-20,000c/s.
Frequency Stability	Total drift from cold approximately 10c/s.
Slow Glide	A synchronous motor and gear box provided to cover the range 20-20,000c/s in 4, 8, 16 or 32 minutes.
External Drive	Provision is made for driving the variable capacitor by external means.
Power Consumption	Approximately 50 watts at 200-250 volts, 50c/s.
Dimensions	Outside dimensions of carrying case 17in. × 10in. × 6in.
Weight	20lb.

† *Patent Application No. 22273/49.*

* *Research Department, BBC Engineering Division*

General Considerations

The requirement of a frequency range of 20-20,000c/s on a single dial made the choice of a beat frequency oscillator almost inevitable. The second requirement, a logarithmic scale, presented a difficult problem as commercial capacitors with a logarithmic law and sufficient maximum capacity are too large to be accommodated in the standardized miniature apparatus box of the B.B.C. Research Department. This difficulty was overcome by using a three-terminal capacitor in the form of a piston attenuator for the incremental capacitor of the variable oscillator. As is well known, this device has the property of giving a transfer capacitance, from the fixed to the moving electrode, which bears a logarithmic relationship to the distance between the electrodes, provided they do not approach one another too closely, i.e., C varies as e^{-kx}, where C is the capacitance, x the distance between the plates, and k a constant. This transfer capacitance is too small to be used directly, but by connecting it between the output and input terminals of an amplifier, the capacitance can be increased to a suitable value by Miller effect. Furthermore, a cyclic variation in the gain of the amplifier will produce a warble tone with, to a first order, a fixed percentage deviation of the set frequency.

A pot type ferrite core is used for the oscillator coils, as this gives the advantages of a high Q and almost complete magnetic screening—a point of considerable importance when the oscillators have to be close to one another. Two slight disadvantages of the material are its high dielectric constant and core losses, both of which increase with temperature. The temperature rise is kept small by thermally insulating the coil boxes from the rest of the apparatus, and the self capacitance of the coils is further reduced by insulating the core from the frame.

The apparatus is constructed on the unit principle which greatly facilitates manufacture and maintenance. The views of Fig. 1 show how this has been accomplished, and Fig. 2 is a circuit diagram.

The Variable Oscillator

The variable oscillator (Fig. 3) consists of three parts, an oscillator V_1 and V_2, an anode follower V_3 and the warble valve V_4. V_1 and V_2 form an amplifier of fixed gain determined by the ratio (160:1) of the feedback transformer T_1. This, combined with the forward gain of 80db,

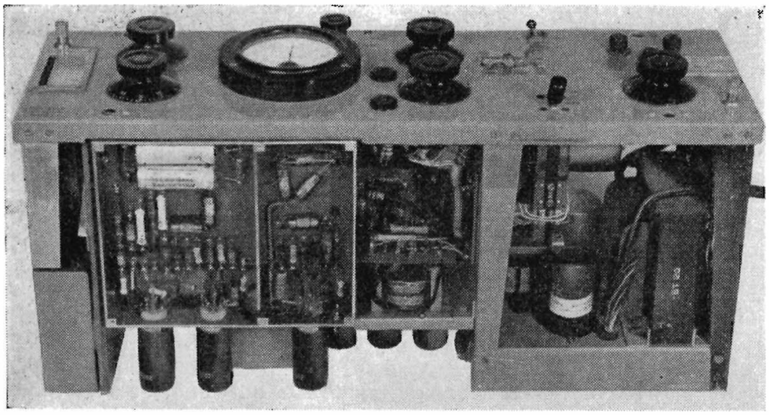


Fig. 1(a). The complete equipment showing the unit construction

gives 36db of negative feedback, which is considered adequate to prevent changes of gain with variations in mains voltage and valve characteristics. Regulated positive feedback is obtained from the anode of V_2 to the grid of V_1 through the resistances R_1, R_2 and the reversed parallel germanium crystals W_1 and W_2, one of which is biased from the cathode of V_2. The square waveform of the positive drive has a precise value determined by the delay volts on W_2 and has the effect of giving good regulation without changes of frequency.

The anode follower V_3 gives an amplification of 2 : 1 determined by the ratio of R_3 to R_4, and its low impedance output is used to feed the moving electrode of the three-terminal capacitor C, which is varied to alter the frequency of the oscillator.

It will be noted that the capacitor C is connected between the input and output of a three-stage amplifier and, consequently, due to Miller effect, appears to the coil as a capacitance $(1 + A)C$, where A is the amplification of the amplifier. Care has to be taken to prevent any phase errors occurring in the amplifier, as these will either increase or decrease the amplitude of oscillation. In practice a slight unavoidable phase displacement is corrected by a small capacitor across R_4.

In a beat frequency oscillator it can be shown that, to a first order, the beat frequency is $f_1\delta C_2/2C_2$, where f_1 = fixed oscillator frequency, δC_2 = the incremental capacitance, and C_2 = total tuning capacitance required to produce f_1. (See Appendix 1). Hence, in order to obtain a warble the deviation of which is a fixed percentage of the set beat frequency, it is only necessary to change δC_2 by a fixed percentage. This can be accomplished quite simply as δC_2 is the effective incremental capacitance of the tuning capacitor and depends directly upon the gain of the amplifier. Thus, variation of this gain will produce a frequency warble in which the deviation from the beat frequency is a fixed percentage of the set beat frequency.

In Fig. 3, V_4 is a transitron oscillator having a frequency of 7c/s determined by C_2, R_5 and C_3, R_6. It is used to modulate the variable oscillator signal which is applied to the control grid and the resultant modulated waveform is injected, with the correct amplitude and phase, into the grid circuit of V_3 so as to produce the necessary change of gain to give the 10 per cent deviation required. The warble has to deviate equally about the set beat frequency, and this is accomplished by adjusting R_7, with the transitron oscillator inoperative, until there is no change of frequency on closing the switch S.

One other point of interest is the method of obtaining the correct phase adjustment of the modulated waveform. As the input capacitance of the variable capacitor is across the anode load of V_3 it causes the grid voltage of V_4 to lag. This is compensated by feeding a leading voltage through C_4, R_8. It is essential that this adjustment should be correct, as maladjustment causes amplitude modulation.

Fig. 4 shows the variable capacitor with the outer casing (1) removed. It has been designed on kinematic* principles and consists of a fixed electrode (2), a moving electrode (3), and the lead screw (4). Rotation of the dial and lead screw moves the carriage (5) by means of a steel ball riding in the screw thread and held there by two spring loaded balls (6) on the opposite side. To prevent stressing the mechanism in the event of over-running the end of the travel, the ball can lift out of the thread and the two balls side by side prevent the wrong ball from re-locating in the thread. The carriage is prevented from rocking by the inverted V-shaped member (7) which houses four steel balls sliding on the guide rod (8). Connexion is made to the moving electrode by a phosphor bronze spring (9), which is soldered to the anchor points at both ends to ensure good electrical contact. The lead screw is carried on two " V " bearings and held there by two spring loaded balls (10) and (11). The ball (10) rests in a groove on the drive shaft to prevent endwise movement, whereas ball (11) rides on the shaft.

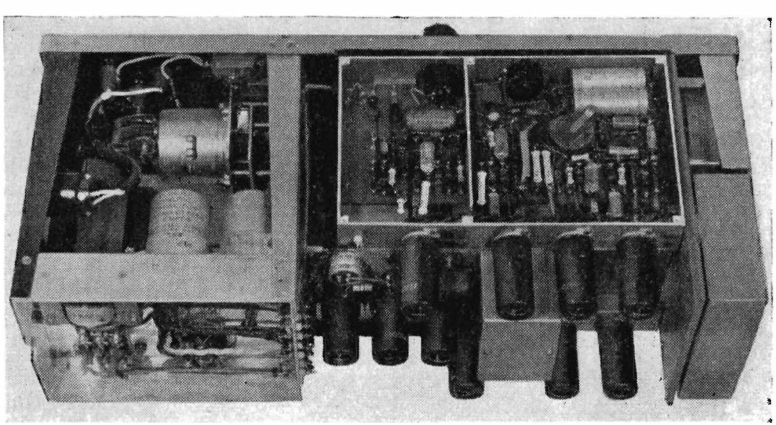
A plot, Fig. 5, of capacitance against angular displacement of the drive shaft shows that the logarithmic law is well maintained over most of the range, but that the inverse distance law causes the capacitance to rise faster as the electrodes approach one another. The departure from the true logarithmic law is used to compensate for the fact that the beat frequency is no longer inversely proportional to the incremental capacitance at high beat frequencies, the squared term in Equation 2 of Appendix 1 necessitating a more rapid rise of capacitance to maintain a logarithmic law at high frequencies.

The Fixed Oscillator

This is a conventional tuned grid oscillator with " reaction coil " feedback from the screen grid of V_1. There are several interesting features in the design which help to achieve the requirements of low harmonic content and constant output level. A simplified circuit diagram is shown in Fig. 6.

** The word " kinematic " is used to describe the technique of instrument design in which accurate movements or displacements are achieved by using the minimum necessary number of constraints to the moving parts rather than extremely accurate workmanship in manufacture.*

Fig. 1(b). Another view of the complete unit



E

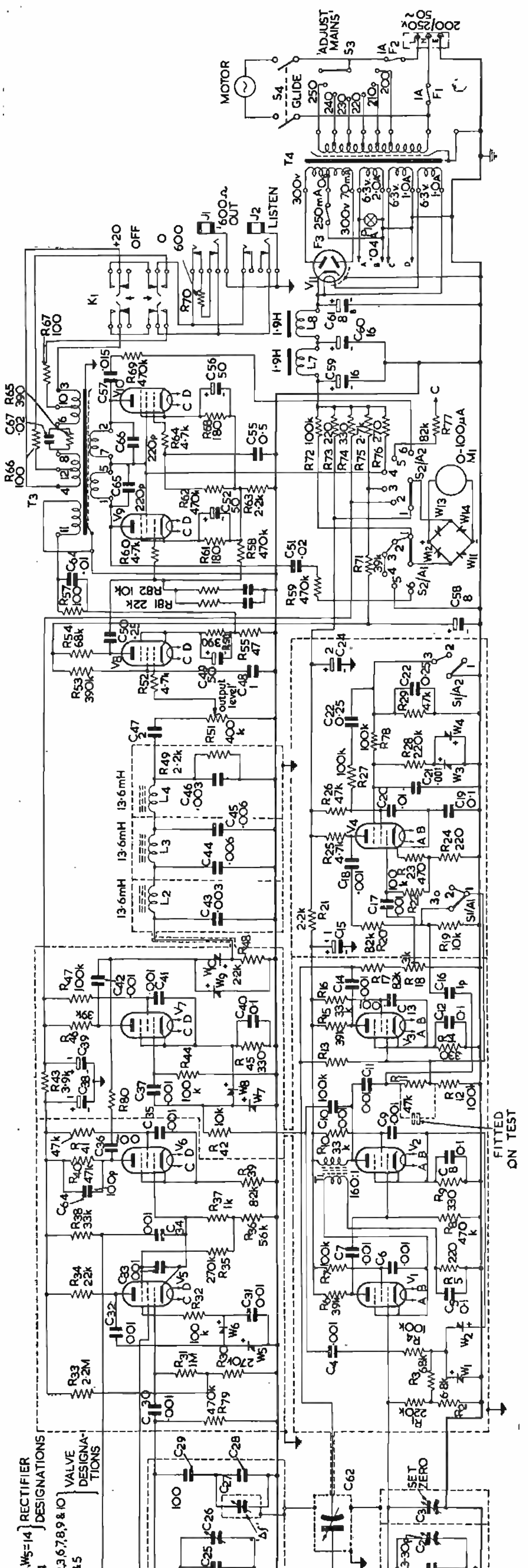


Fig. 2. Circuit diagram of the complete unit

A frequency of 150kc/s was chosen for the fixed oscillator as a compromise between frequency stability and departure from a logarithmic scale for the beat frequency.

Regulation is obtained by suitable division of the screen and anode currents of V_1. The suppressor grid is biased negatively and obtains a countering positive bias, proportional to the oscillator voltage, from the voltage doubling circuit W_1W_2 fed from the anode and delayed by the voltage across the cathode resistor R_1. Thus, if the oscillator voltage rises, the suppressor grid is made more positive and the screen grid current reduced, thereby reducing the amplitude of oscillation and vice versa. Heavy cathode feedback is employed and in order to provide correct working conditions the grid is returned to a point some 30 volts positive to ground. This arrangement, although dependent upon the H.T. supply for stability, gives adequate regulation, but should at any time better regulation be required, it can be obtained easily by stabilizing the grid voltage with a neon lamp. A regulation curve showing output volts against coil loss is shown in Fig. 7. It will be noted that an additional 2 micromhos of damping had to be added to arrive at a suitable working point as it was inconvenient to reduce the positive drive from the reaction coil or the screen grid current.

A low-pass filter R_2 C_1 is used to reduce harmonics and couple the output from the cathode of V_1 to the grid of V_2 which acts as a buffer stage to feed the mixer. Considerable cathode feedback is again used for stability and freedom from harmonics.

The ± 50c/s increment is obtained by a small trimmer across the main tuning capacitor of the fixed oscillator. As the increment calls for a change of capacitance of only ± 1pF a larger capacitor was chosen and suitably padded out as shown in Fig. 6 where C_2 represents the trimmer, and C_3 and C_4 the padding capacitors.

The trimmers, like the variable capacitor, are designed on kinematic principles, and in order to obtain a smooth bearing, use has been made of polytetrafluoroethylene for the bearing surface. An assembly view is shown in Fig. 8.

The Mixer

This circuit, shown in Fig. 6, is of particular interest as it produces a beat frequency output which is substantially free from harmonics. Two methods are commonly employed for obtaining the audio signal in a beat frequency oscillator. One is to multiply the two high frequency signals by passing them through a square law device which, unless it is exactly square law, will produce harmonics of the beat frequency. The output voltage in this type of mixer is proportional to the product of the fixed and variable oscillator voltages.

The second method is to add the two signals and obtain the beat frequency by linear rectification. This is equivalent to a single sideband modulated carrier and will give distortion unless one of the signals is small compared with the other. In this condition the output voltage is proportional of the smaller signal.

The method employed here makes use of the fact that the amount of beat frequency harmonic obtained when two high frequency signals are added and linearly rectified depends only upon the purity of one of the wave-forms and the maximum rate of change of voltage (or current) of the other. It follows that, if a pure sine wave is added to a rectangular wave of slightly different frequency, the resulting beat frequency from linear rectification will have no harmonics and, if the sine wave contains harmonics, the beat frequency will have no even harmonics and greatly reduced odd harmonics. A mathematical treatment of the theory has been established and it is hoped to publish the results at an early date[1].

The output of some 25 volts from the variable oscillator is squared by R_3 and the biased rectifiers W_3 W_4 on the grid of V_3 (Fig. 6). After amplification the square waveform is added to the pure waveform (10 volts) of the fixed oscillator and linearly rectified by the rectifiers W_5, W_6. The audio frequency output is obtained from the low-pass filter which forms the rectifier load and is used to suppress the primary oscillator components and other rectification products.

The Audio Frequency Amplifier

This is a two-stage amplifier with push-pull output and negative feedback from a tertiary winding on the output transformer to the cathode of the first stage. It is of similar design to that described in a previous article.[2]

The maximum output is + 20db above 1 milliwatt into a 600 ohm load, but owing to limitation on the size of the output transformer the maximum output is not obtainable below 50c/s.

The Power Supply Unit

The supply unit gives 70mA at 300 volts for the anode and screen supplies and 6.3V, 4A for heaters. A cold cathode rectifier (OZ4) is used for economy in heater power and to keep the temperature rise as small as possible. The valves are divided into groups for metering, and an output meter is provided for setting the output level. Table 1 gives the list of valves used and their feeds.

The Slow Glide

A small synchronous clock motor and a four-speed gearbox (Fig. 9) are provided, so that the frequency sweep of 20-20,000c/s can be covered in approximately 4, 8, 16 or 32 minutes.

A universal joint, through which the drive is transmitted by three spring-loaded balls resting in grooves, is interposed so that overdriving will not damage either the variable capacitor or the gearbox. A shaft is also available for driving the variable capacitor from an external source.

Performance

FREQUENCY CHARACTERISTIC: — This is within ±0.25db from 20-20,000c/s. A slight drop at the extreme ends of the band is attributable to the audio frequency amplifier.

HARMONICS AND NOISE LEVEL: —These were found to be low as shown in Table 2. The fact that they do not vary appreciably with output indicates that the audio frequency stage is satisfactory and that the mixer behaves as predicted.

In a paper[3] to be published elsewhere it will be shown that the distortion due to pulling at a frequency f when the locking frequency of the oscillators is f_0 is given by

$$\text{Distortion} = \frac{f_0}{2f} \times 100 \text{ per cent.}$$

Hence it can be seen that distortion from this cause is quite small.

The hum and noise level at 57db below maximum output is considered satisfactory.

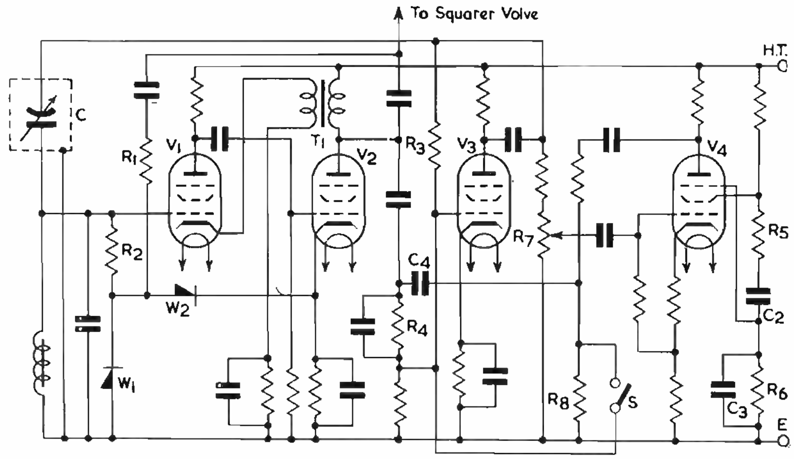


Fig. 3. The variable oscillator (simplified)

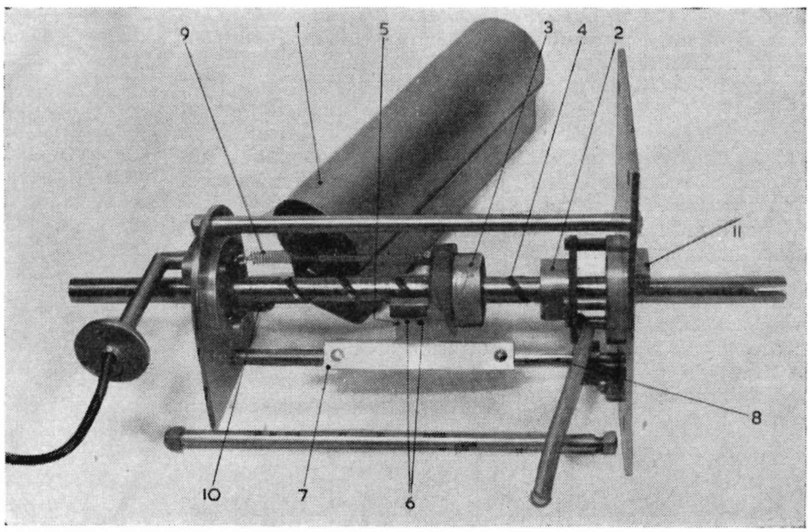
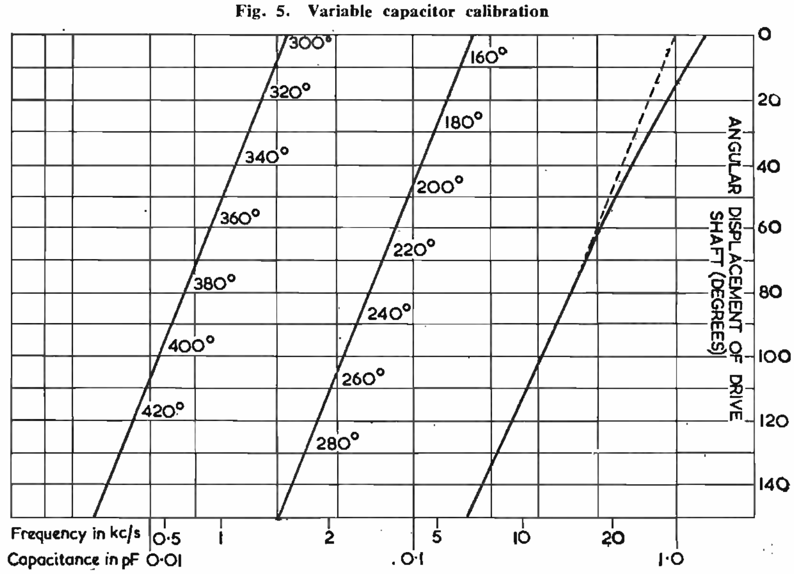


Fig. 4. The variable capacitor

Fig. 5. Variable capacitor calibration



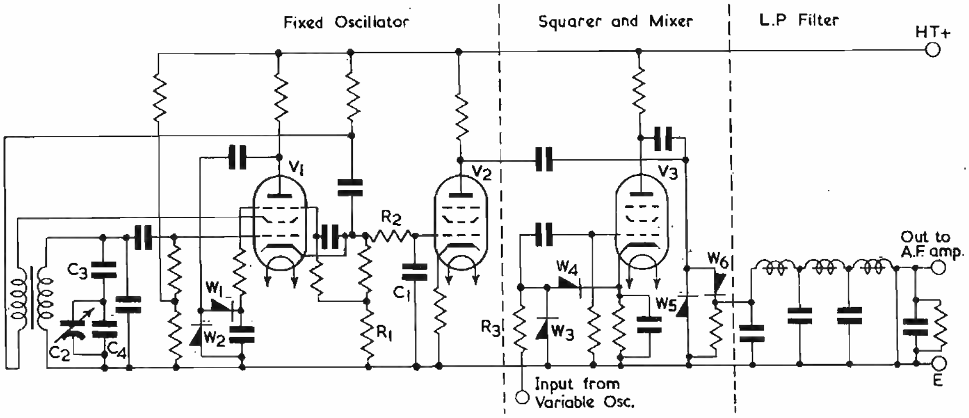


Fig. 6. The fixed oscillator squarer and L.P. filter (simplified)

DRIFT:—Typical drift curves are shown in Fig. 10, from which it will be seen that, although the oscillators drift a total of some 60c/s from cold, they keep in step so that the beat frequency drift is small enough to be considered satisfactory for a portable oscillator of this size. The drift is mainly attributable to heating of the coils and capacitors both of which have a temperature coefficient of up to + 50 parts per million per degree centigrade. Thus a 10°C. rise will give a change of frequency of up to 75c/s. From the shape of the curves it is obvious that a small negative temperature compensating capacitor could be used to reduce the drift, but its value would have to be found experimentally for each tone source.

The frequency scale was calibrated on opal perspex which is illuminated internally by a dial lamp. The decade points were obtained by calibration on a cathode ray oscilloscope against 10,000, 1,000 and 100c/s tone derived from a 1Mc/s crystal oscillator whose absolute frequency is known and whose frequency stability is better than 1 part in 10^7.

The decade points were subdivided on a logarithmic basis. It was found after calibrating six tone sources that the mean calibration curve showed an error of just over ± 2 per cent, which was attributable to errors in the screw thread and diameter of the electrodes and outer casing of the variable capacitor. As these capacitors were produced by normal workshop practice without special regard to precision, this result was considered satisfactory. It should be noted that a high degree of accuracy is required for the division of the scale to prevent the marks from appearing uneven.

SETTING ACCURACY:—As the scale is logarithmic the setting accuracy is constant throughout the frequency range, and is of the order of 1 per cent. No backlash could be detected in the variable capacitor, as the same frequency was obtained when approached from either above or below.

The "zero set" adjustment is made by setting the main dial to 50c/s, reducing the incremental dial by 50c/s, adjusting for zero beat on the "set zero" control and returning the incremental dial to its original setting. This somewhat elaborate arrangement is necessary, as with a logarithmic scale there is no zero. If some arbitrary zero had been chosen at 0.2c/s, say, a scale length equivalent

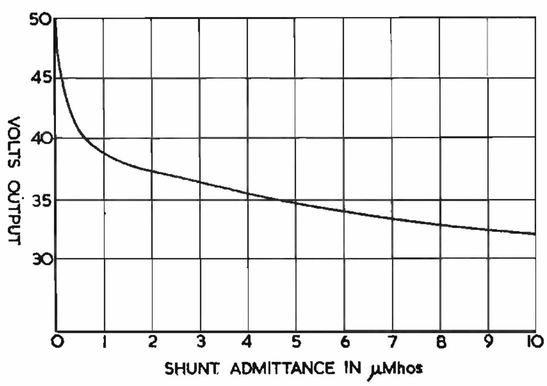


Fig. 7. Regulation of fixed oscillator

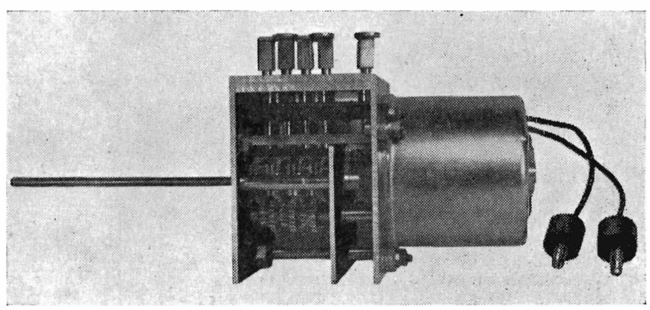


Fig. 9. The gearbox and motor

Fig. 8. The trimmer capacitor

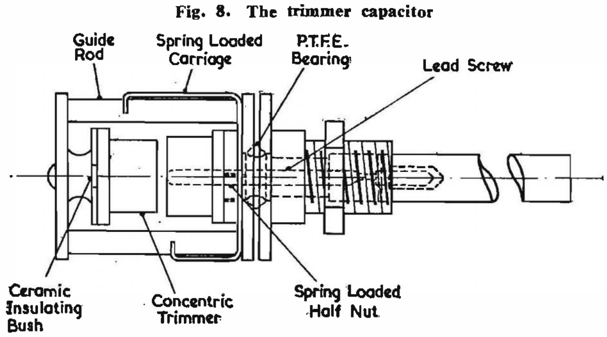
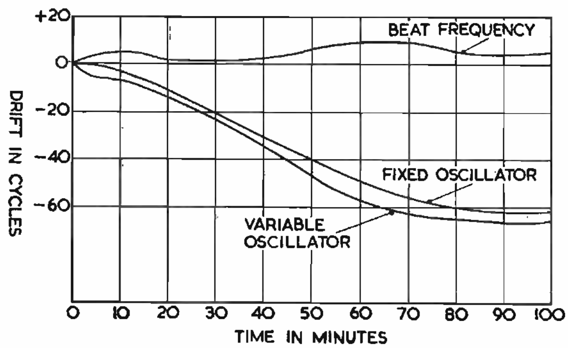


Fig. 10. Typical drift curves



to twice that of 20-200c/s would have been lost. An alternative method of injecting 50c/s from the mains could be used, but it would require an additional control on the front panel.

Acknowledgments

The authors wish to thank their colleagues of the B.B.C. Engineering Research Department for help in the development of this tone source and they are also indebted to the Chief Engineer of the B.B.C. for permission to publish this article.

APPENDIX

Relationship of Beat Frequency and Incremental Capacitance

Let $f_1 = K_1/C^{\frac{1}{2}}$ and $f_2 = \dfrac{K_2}{(C_2 + \delta C_2)^{\frac{1}{2}}}$

where f_1 = fixed oscillator frequency

f_2 = variable oscillator frequency

C & C_2 = values of main tuning capacitor

δC_2 = values of incremental tuning capacitor

and K_1 and K_2 are constants.

Then the beat frequency F is given by

$$F = f_1 - f_2 = K_1/C^{\frac{1}{2}} - \frac{K_2}{(C_2 + \delta C_2)^{\frac{1}{2}}}$$

$$= f_1 \left[1 - \frac{1}{(1 + \delta C_2/C_2)^{\frac{1}{2}}} \right] \quad \ldots\ldots\ldots (1)$$

since $f_1 = K_1/C^{\frac{1}{2}} = K_2/C_2^{\frac{1}{2}}$, i.e., $\lim_{\delta C_2 \to 0} f_2 = f_1$

$$F = f_1 \left[1 - \left(1 - 1/2\, \delta C_2/C_2 + \frac{1/2 \,.\, 3/2}{1 \,.\, 2} \left(\frac{\delta C_2}{C_2} \right)^2 - \frac{1/2 \,.\, 3/2 \,.\, 5/2}{1 \,.\, 2 \,.\, 3} \left(\frac{\delta C_2}{C_2} \right)^3 + \ldots \right) \right]$$

$$= f_1 \left(\frac{\delta C_2}{2C_2} - 3/8 \left(\frac{\delta C_2}{C_2} \right)^2 + 5/16 \left(\frac{\delta C_2}{C_2} \right)^3 - \ldots \right) \ldots\ldots (2)$$

$$\simeq f_1 \frac{\delta C_2}{2C_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Thus so long as $(\delta C_2/C_2)^2$ is small compared with $\delta C_2/C_2$, the beat frequency is proportional to δC_2. Above this point the scale will open out. Hence a logarithmic capacitance law for the variable capacitor results in a substantially logarithmic frequency scale.

TABLE I

Valve No.	Type	I_amA	I_{g2}mA
V_1	CV138	4.0	1.25
V_2	CV138	6.0	1.7
V_3	CV138	3.8	1.0
V_4	CV329	3.2	3.2
V_5	CV329	3.3	2.6
V_6	CV138	3.3	1.0
V_7	CV138	4.8	1.4
V_8	CV138	1.6	0.5
V_9	CV138	10.0	2.5
V_{10}	CV138	10.0	2.5
V_{11}	OZ4	—	—

(H.T. = 300 volts AC input = 52VA)

TABLE II

Frequency c/s	Output Level	Harmonics Percentage		
		2nd	3rd	
60	+20	.44	.5	Higher harmonics negligible
	0	.35	.35	
1000	+20	.22	.35	
	0	.16	.32	
5000	+20	.23	.33	
	0	.20	.30	

(Hum and noise 57db below maximum output)

REFERENCES

1 Mayo, C. G. Mathematical Theory of Mixing in a Beat Frequency Tone Source. *To be published in Wireless Engineer.*

2 Shorter, D. E. L. and Beadle D. G. " A Portable Microphone to Line Amplifier." *Elect Engg. xxiii*, 126, (1951).

3 Mayo, C. G. Mathematical Theory of Distortion due to Pulling in a Beat Frequency Tone Source. *To be published in Wireless Engineer.*

The Electronic Telescribe*

THE Electronic Telescribe is the name given to a unit which was used to demonstrate the application of photo-electric cells and cathode-ray tubes by Messrs. Mullard, Ltd., at the National Radio Exhibition.

It consists of two units linked together by a single cable. When the glass plate of the first unit is written upon, a small cathode-ray tube and photocell transfers the pencil marks into electric currents. These are conveyed to the second unit (a very slightly modified commercial television receiver) where they are changed back into a visible reproduction of the original writing.

This simple equipment is fully capable of reproducing photographs, drawings and printed matter laid face down upon the glass plate and in this way it offers an excellent and greatly simplified medium for picture transmissions. While the model shown is limited to 200-line definition, Mullard engineers state that, with only a few minor modifications, this could be extended to a full 1,000-line system. Under these conditions, picture reproductions of near-photographic quality could be readily obtained.

Although not originally intended as a commercial instrument, the principle of the Telescribe could, certainly be adapted to a number of important practical applications. Its most important application is undoubtedly the superimposition of maps on radar display screens. This has obvious value in all radar display systems.

The Electronic Telescribe utilizes, in a special manner, the principle known as the flying-spot scanning technique. The time bases of two cathode-ray tubes—one a " transmitting " and the other a " receiving " tube—are synchronized. In the transmitting unit, a raster is produced on the screen of a special Mullard projection tube. By means of an optical system, the light from this raster is projected on to the glass writing plate at the top of the unit. In this way the glass plate is continuously scanned by a pencil of light.

In the absence of any picture or writing, the light beam passes through the glass plate. If a mark is made on the plate, however, some of the light is reflected and dispersed, and is picked up by a photocell. Electric currents, corresponding to the light variations, are in this way produced. These currents are amplified and are then used to modulate the beam on the " receiving " cathode-ray tube, which, being synchronized with the " transmitting " tube, will trace " bright " or " dark " in sympathy. In this way a visible reproduction of the original work is immediately produced.

*Communication from Mullard Ltd.

A Simple "Q" Meter

By W. R. Hinton, A.M.I.E.E.

THE design and construction of a simple Q meter based on well known laboratory methods is described with sufficient flexibility to enable a constructor to utilize his available components. One feature, which may find application in other fields, is the design and construction of a variable capacitor of range 0.02 *to* 0.5*pF, and another is the very robust valve voltmeter which does not require a highly sensitive deflecting instrument.*

TO anyone with limited facilities, the construction of a conventional type of Q meter presents two serious difficulties. The first is the construction and calibration of the resistor used for injecting the known E.M.F. into the resonant circuit, and the second is the construction and calibration of a stable valve voltmeter for measuring the resonant voltage and hence the Q. Further, these calibrations must be stable absolute ones, as distinct from relative ones, because the units of the quantities involved in the measurement of Q are dissimilar.

The problem of making the injection resistor is avoided in one promising technique,[1] which is to use a capacitative voltage divider for the injection circuit. Also, by switching the same valve voltmeter from the input of the potential divider to the resonant circuit under test, only a stable relative calibration would be required.

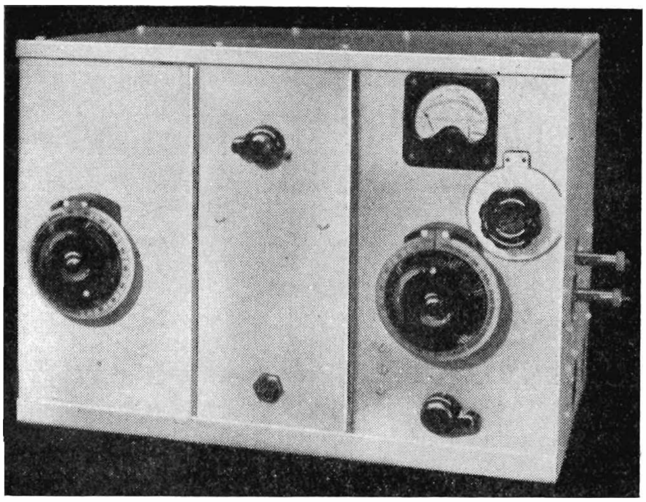


Fig. 1. "Capacitance Variation" Q meter

The instrument to be described avoids the need for any meter calibrations and the only relative calibration required for the Q measurement can be done by turn counting. The measurement of inductance involves the calibration of oscillator frequency, which can be done with broadcasting stations and a little ingenuity,[2] and the resonant test circuit capacitance needs to be calibrated as assembled and working, which is easily done if a reference standard variable capacitor can be borrowed.

Two versions of the instrument are possible as the principle of operation can be either "frequency variation"[3] or the "capacitance variation"[4] method which involves mistuning a resonant circuit to reduce the voltage to a given fraction of the maximum possible by changing the existing frequency or the tuning capacitance respectively.

Fig. 1 shows the "capacitance variation" version made by the author, where the mistuning is done by a small trimmer capacitor across the main tuning capacitance and the ratio of maximum resonant voltage to mistuned voltage is determined by a stable wire wound potential divider forming the load of a cathode follower. (See Fig. 2.)

The operation of the instrument is extremely simple. The coil under test is connected to the two terminals and the trimmer capacitor control is set to a reference mark. Then with the switch at A resonance is obtained by adjusting the exciting frequency and the main tuning capacitance, the coupling capacitor being adjusted to give a convenient reference deflexion on the indicator. The switch is then set to B and the trimmer capacitor is adjusted to restore the indicator deflexion to the reference value. (Thus long term stability and calibration of the valve voltmeter is not important.)

Then if: C = Capacitance tuning the coil at resonance,

ΔC = the change in capacitance of the trimmer capacitor.

and ω = is the angular frequency of test.

$$Q = \frac{C}{\Delta C} \qquad \ldots\ldots (1)$$

$$L = \frac{1}{\omega^2 C} \qquad \ldots\ldots (2)$$

(If the instrument is used for factory checking one particular size of coil, C can be fixed and the trimmer capacitor calibrated directly in Q, and the frequency control directly in inductance.)

In the "frequency variation" version, the corresponding equation for Q is:

$$Q = \frac{f}{2\Delta f} \qquad \ldots\ldots (3)$$

where f is the resonant frequency

and Δf is the deviation from the resonant frequency to reduce the voltage to 0.7071 of the maximum.

A direct calibration of Q could be obtained on the cursor of the frequency control if a logarithmic capacitor is used for tuning the oscillator because then the same mechanical angle of mistuning corresponds to the same value of Q at any part of the scale. The method of observation would be to note the shift of a convenient main dial mark along the Q cursor corresponding to the switch positions A and B. However, for the home constructor, the capacitance variation version is easier to make and is more precise.

The circuit given in Fig. 2 happens to be one suitable for the limited requirements of the author and was devised around various components which were at hand, and cannot be regarded as the best possible design. Therefore in the notes which follow sufficient design information is given to enable any other constructor to fit his own components and ideas in, or perhaps use some of the features elsewhere.

The Valve Voltmeter

The design of the Q Meter starts from the choice of the deflecting instrument used as the reference indicator, and a cathode coupled double triode is used as the most convenient method of obtaining overload protection of the deflecting instrument and reasonable stability with a minimum number of components.

Overload protection is obtained by the high series resistance in the grid of the first triode with the design condition that the second triode shall cut off at the point the first triode commences to take grid current.

Assuming identical triodes and linear valve mutual characteristics, the basic circuit for development is given by:

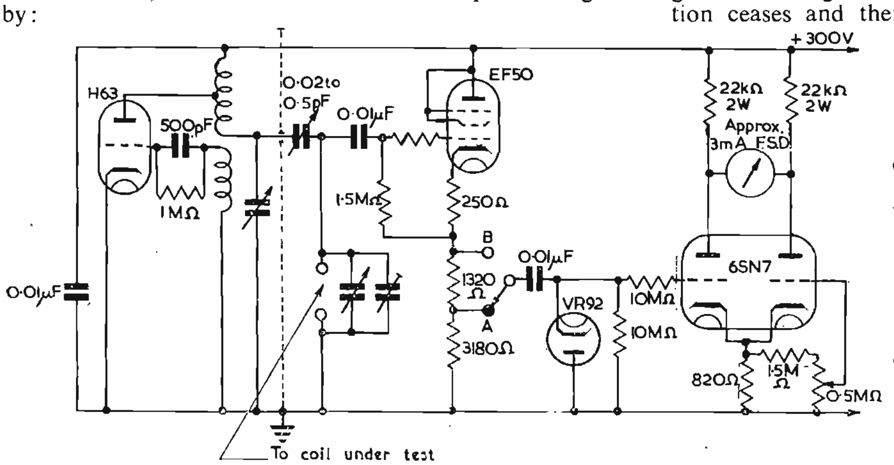


Fig. 2. The Q meter circuit diagram

$$R = R_a/I_M\ (k + V_{HT}/R_a) - 2(R_a + R_K) \quad .... \quad (4)$$

$$R_K = 1/g \quad .... \quad (5)$$

and

$$E = 2\, I_M R_K \quad .... \quad (6)$$

where E = Input P.D. to cause cut off.

R = Anode Load Resistance of each valve.

R_K = Common cathode resistance.

V_{HT} = H.T. voltage of supply to the valves.

I_M = Maximum permissible meter current.

g = Mutual Conductance of the valves.

R_a = Anode Resistance of the valve.

$$k = (i^* - gV_g^* - V_a^*/R_a) \quad .... \quad (7)$$

where g and R_a are as above and i^* is the anode current given in the Valve Manufacturer's Catalogue corresponding to anode voltage V_a^* and grid voltage V_g^*. (Notice that in practice V_g^* will be negative and will therefore affect the sign of the term containing it.)

In practice the valve characteristics are not sufficiently linear to cause simultaneous cut off at the above design conditions and it is usually necessary to increase the bias resistor by a factor of 1.5 or 2.

The Oscillator

Having designed the indicator it is now possible to determine the minimum oscillator voltage required. Now in the frequency variation and capacitance variation methods it is usual to choose the ratio of maximum to mistuned voltage to be $\sqrt{2}$ and it can be shown that the effect of a finite coupling capacitance is to cause the required ratio of voltage to differ from $\sqrt{2}$ by a factor $(1 + V/2E)$ or $(1 + C/2\Delta C)$ approximately. Where:

V = Maximum voltage across the tuned circuit.

E = Oscillator Voltage.

C = Coupling Capacitance.

ΔC = Change in capacitance in the capacitance variation method.

Thus to keep this error to less than 0.5 per cent, it is necessary to have an oscillator voltage more than 100 times the maximum voltage across the tuned circuit, or an alternative conception is that the coupling capacitance must be less than one-hundredth of the expected change in the capacitance variation method.

Obviously it is good practice to use as high an oscillator voltage as possible, certainly at least 100 times the value of E given in Equation (6) peak value, and Fig. 2 shows the anode load of the oscillator used as an auto-transformer, thus giving an output of about $2V_{HT}$, i.e., 600V compared with 4 or 5V peak across the tuned circuit. In the interest of stability and good waveform[5] the oscillator is the tuned anode type with tight grid/anode coupling and low mutual inductance, the correct number of turns in the grid coil being found by counting them off until oscillation ceases and then rewinding with about 10 per cent more than the critical value to allow for valve ageing.

The Coupling Capacitor

The oscillator is capacitatively coupled to the Q measuring circuit because this is probably more convenient than mutual inductive coupling and can be designed with more certainty of the effect of oscillator internal impedance on the Q measurement.

The coupling capacitor in this instrument is a logarithmic variable capacitor of range approximately 0.02pF to 0.5pF over an angle of about 160 degrees and is provided with a zero capacitance setting. The use of a logarithmic law gives the same sensation of control independent of its position within the range.

The capacitance range is decided from the range of Q required, the ratio of oscillator voltage to the resonant voltage and the capacitance to tune the coil under test. The maximum and minimum value of coupling capacitance is obtained from:

$$C = C_o/\rho Q \quad .... \quad (8)$$

where $\rho = E/V$

and C_o = capacitance to tune the coil.

The low capacitances required are obtained by insertan earthed screen between the capacitor electrodes and arranging for a control to vary the area of an aperture which exposes one electrode to the other. Neglecting fringing of the lines of electric force, the required aperture area is given by:

$$A = 4\pi t\,.\,C \quad .... \quad (9)$$

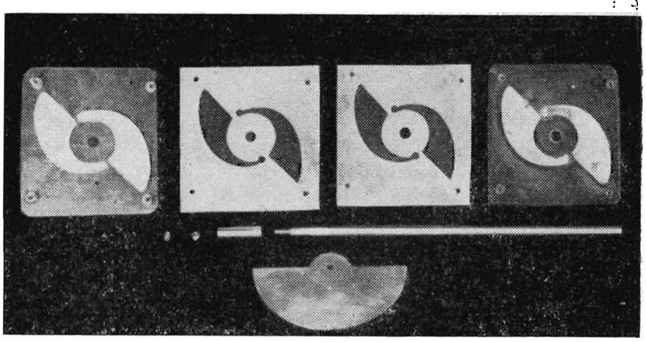


Fig. 3. Exploded view of the 0 02 to 0.5pF coupling capacitor

where A is the area of aperture in sq.cm.

t = distance between the parallel electrodes in cm.

C = the required capacitance in cm.

Fig. 3 shows the exploded view of the capacitor in which a semi-circular shutter works between earthed plates provided with horn shaped apertures. The capacitor electrodes are thin copper foils on perspex sheets. In this particular application the shape of the electrodes approximate the shape of the apertures so as to reduce the capacitance to earth to a minimum. Further, the capacitor is a double complementary unit so that with the oscillator connected to two electrodes on the same side of the screen, it always "looks out" into the same total area of distant electrodes. One distant electrode is earthed and the other is connected to the resonant circuit and is almost at earth potential, therefore the oscillator always looks out into the same capacitance and therefore its frequency is not affected by the position of this control.

The horn-shaped aperture is formed by a constant inner radius r and a variable outer radius R given by:

$$R = \left[2A_{min} \left(\frac{A_{max}}{A_{min}} \right)^{\theta/\alpha} \text{Log}_e \left(\frac{A_{max}}{A_{min}} \right) + r^2 \right]^{\frac{1}{2}} \ldots\ldots (10)$$

where A_{min} (sq.cm) = Minimum area at $\theta = 0$.
A_{max} (sq.cm) = Maximum area at $\theta = \alpha$
α (radians) = Angle of shutter between A_{max} and A_{min}
θ (radians) = Angle of shutter from A_{min}
r (cm) = Inner radius of aperture
R (cm) = Outer radius of aperture

Notice that at $\theta = 0$, an area A_{min} must be exposed, and this can be of any convenient shape and is the small circle at the narrow end of the horn. Also by choosing $\alpha \cong 0.9\pi$ the useful facility of cutting off the oscillator feed is provided as the shutter completely covers the aperture feeding the test circuit and the screen of the capacitor divides the coupling compartment into two as shown in Fig. 4.

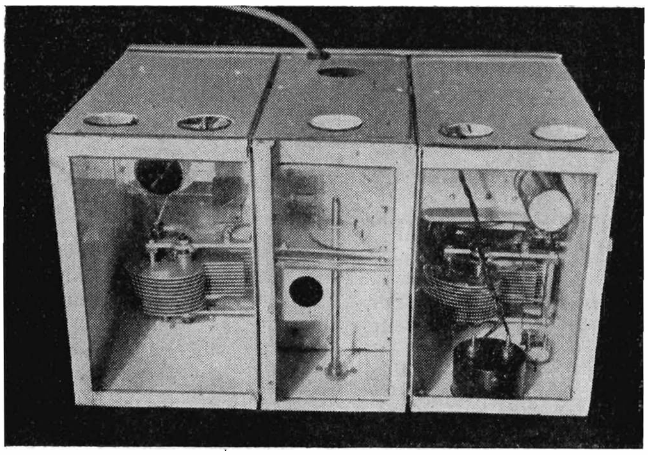


Fig. 4. Top view showing the assembled coupling capacitor

The Cathode Follower

The load of the cathode follower consists of a uniformly wound resistance wire on a thin parallel card, tapped at a point 0.7071 of the total resistance either by turn counting or measurement. When making this component it is quite convenient to include another wire wound section for the bias resistor. (If one is to rely on turn counting for the tapping position, considerable care must be taken to see that the resistor card is parallel and the edges nicely rounded so as to avoid over stressing the wire during winding, and a minimum tension consistent with uniformity of winding should be used.)

It may be noted that it is not essential for the potential divider to be purely resistive at the frequency used so long as the impedance ratio is correct. Therefore, provided the card is thin there is little inductive coupling between turns, the self inductance of the resistor increases approximately in proportion to the first power of the number of turns, instead of to the square, as it would be for a solenoid where appreciable coupling exists between widely separated turns. Furthermore, any inductive reactance is in quadrature with the resistance so that any inherent errors in the ratio of inductance have a correspondingly smaller effect on the voltage ratio. The actual ratio obtaining at any frequency can, of course, be checked directly by observing the indicator deflexions corresponding to switch positions A and B, using as a reference the deflexions obtained at low frequencies, say in the order of hundreds of kc/s, where the potential divider ratio is in no doubt,[6] and the following correction can then be applied if required:

$$\text{True Q} = \sqrt{q^2 - 1}\ .\ \text{Indicated Q} \ldots\ldots (11)$$

where q = Ratio of Maximum Voltage to the Minimum.

The choice of the valve will depend on the resistance wire and winding facilities available, but every effort should be made to design this stage with as high an input impedance as possible as this directly affects the precision of the Q measurement. Having made the Q meter, it is possible to check the order of this input impedance by feeding a temporary duplicate cathode follower from the Q meter supply, and observing the reduction in Q when it is connected across the test coil.

Mechanical Layout

In making this instrument it is necessary to give some thought to the mechanical disposition of the components and units. The coupling capacitance of the order of 0.05pF implies the need for adequate screening of the oscillator from the Q measuring circuits, if this component is to function correctly; and the facility of having zero capacitance coupling is very useful in practice to check that everything is working satisfactorily. The use of screened leads is to be avoided, first because of their high lead to earth capacitance and, secondly, this latter capacitance may be unstable and so upset the various tuning calibrations. Therefore the author used a three-unit construction in which the central unit separates the oscillator from the Q measuring circuits and the power pack is contained on the underside of an internal shelf.

This shelf forms a convenient upper compartment containing the coupling capacitor which, in turn, divides this into two parts. Connexions to the coupling capacitor are made by bare wires to copper pegs in the centre of perspex insulators bolted to the sides of the compartment. These pegs project, one into the oscillator compartment and one into the Q meter compartment through adequate clearance holes provided in the walls of these units.

Conclusions

Experience has shown that it is possible to make a very satisfactory and inexpensive Q meter using Government surplus parts and general components without any special facilities other than being able to borrow a calibrated capacitor. The instrument is so robust and easy to operate that it could be adapted for factory testing by non-technical personnel as it would be a simple matter to calibrate the dials with limit marks.

With careful construction and calibration, the instrument should give precisions of better than ± 1 per cent in reactance measurements and better than ± 5 per cent in Q at frequencies up to several megacycles, but naturally the frequency at which the correction of Equation (11) becomes necessary will vary between individual instruments, depending on the construction of the cathode follower and, as pointed out in the text, the necessary correction can be found with no extra equipment.

Finally, the author wishes to acknowledge the permission of the Chief Scientist of the Ministry of Supply to publish this article.

REFERENCES

[1] HOWE, G. W. Editorial, *Wireless Engineer, XVI*, 188. (1939).
[2] Modulated Test Oscillator. *Wireless World XLI*, 492 (1935).
[3] TERMAN, F. E. Radio Engineers' Handbook, 13, 5, 913 (McGraw-Hill).
[4] Ibid. 13, 5, 914.
[5] THOMAS, H. A. Theory and Design of Value Oscillators, 8, 188.
[6] TERMAN, F. E. Radio Engineers' Handbook, 2/6/45. Table 8 (McGraw Hill).

Microwave Rotating Joints

(Part 2)

By J. P. Grantham *

Concentric-Line Rotating Joints

This form of rotating joint consists of a rectangular-waveguide-to-concentric-line transformer, followed by a length of concentric line and completed by a second transition. As the dimensions of the concentric line are small, it is not possible to design a satisfactory break in the concentric line and the break is made where the concentric line enters the waveguide. The transition must be of a symmetrical nature, to permit rotation of the inner conductor of the concentric line. The principal mode is always used, the concentric line being operated below cut-off for all higher modes.

THE OPTIMUM DIMENSIONS FOR THE CONCENTRIC LINE

In cases where voltage breakdown considerations do not arise, the concentric-line parameters may be chosen to suit the impedance characteristics of the transformer employed; a fairly high characteristic impedance is usually preferred (100 to 200 ohms). However, it is usually necessary to design for the best voltage-breakdown properties. As some confusion exists regarding the correct choice of concentric-line parameters, it would be as well to discuss this question in detail. For simplicity, air-filled lines are considered.

The lowest mode with a non-vanishing cut-off wavelength is the $H_{1,0}$ mode. The expression for the cut-off wavelength is somewhat complex, and depends upon the ratio of the radii of the conductors, b/a, as well as on their sum $(a + b)$. If the expression for λ_c given below be taken, the error will be less than ± 1 per cent over the range $b/a = 1.8$ to $b/a = 2.7$.

$$\lambda_c = \frac{(a+b)\,.\,\pi}{1.015} \quad \ldots\ldots\ldots\ldots (2.1)$$

E (= the electric field intensity) is a maximum at the centre conductor and the voltage V is given by

$$V = \int_a^b \frac{E\,.\,a}{r}\,dr = E\,.\,a\,.\log_e b/a \quad \ldots. (2.2)$$

now, the power flowing in a travelling wave is given by

$$W = \tfrac{1}{2}VI$$
$$= V^2/2Z_0 \text{ where } Z_0 = 60\,.\log_e b/a$$

which gives

$$W = \frac{E^2\,.\,a^2}{120}\,.\log_e b/a \quad \ldots\ldots\ldots\ldots (2.3)$$

The expression for optimum line parameters is usually obtained as follows:

for a given power W, and outer radius b we have

$$E^2 = \frac{120\,.\,W}{a^2\,.\log_e b/a}$$

giving

$$\frac{2E}{120W}\,.\,dE/da = \frac{1\text{-}2\log_e b/a}{a^3(\log_e b/a)^2}$$

for minimum E $\log_e b/a = \frac{1}{2}$

$$\text{or } b/a = 1.65 \quad \ldots\ldots\ldots\ldots\ldots (2.4)$$

However, in the case being considered we require to know the optimum parameters for minimum E consistent with the condition that the line is below cut-off for higher modes. We must therefore consider $(a + b)$ as constant, see Equation (2.1).

Let

$$p = a + b = 1.015\lambda_c/\pi \quad \ldots\ldots\ldots\ldots (2.5)$$

Then

$$E^2 = \frac{120\,.\,W}{a^2\log_e(p-a)/a}$$

giving

$$2E/120W\,.\,dE/da = \frac{p - 2(p-a)\log_e(p-a)/a}{a^3(p-a)(\log_e(p-a)/a)^2}$$

for minimum E

$$\log_e(p-a)/a = \frac{p}{2(p-a)} \quad \ldots\ldots\ldots\ldots (2.6)$$

or $e^y = 1/(2y - 1)$ where $y = p/2(p-a)$

This gives $y = 0.739$ .... (2.7)

Therefore $p = 3.092a$

The optimum line parameters for minimum E are therefore given by

$$a + b = 1.015\lambda_c/\pi \quad \ldots\ldots\ldots\ldots (2.1)$$
$$b/a = 2.092 \quad \ldots\ldots\ldots\ldots (2.8)$$

This gives the characteristic impedance

$$Z_0 = 44.29 \text{ ohms} \quad \ldots\ldots\ldots\ldots (2.9)$$

The above equations refer to air-filled lines. When the dielectric has a dielectric constant k, λ_c in Equation (2.1) should be divided by $k^{\frac{1}{2}}$ and W in Equation (2.3) should be multiplied by $k^{\frac{1}{2}}$.

It can be shown that if minimum conductor loss is required consistent with no higher modes, the optimum value for Z_0 is about 93 ohms. For a fixed outer radius, the figure becomes $Z_0 = 77$ ohms. These figures apply to air filled lines. However, the attenuation in a line given by Equations (2.1) and (2.8) is negligible:

Consider a line where $b/a = 2$

$$\lambda_c = 2.8\text{cm}$$
$$\lambda = 3.2\text{cm}$$

taking copper conductors where $\sigma = 5.8 \times 10^7$mhos/m and an air filled line.

$$\text{Then } \alpha = 0.0457\sqrt{\frac{1}{\sigma\lambda}} \times \frac{1 + b/a}{b\log b/a} \text{ nepers}/m$$
$$= 1.97 \times 10^{-3}\text{db/cm.}$$

It remains to determine whether the voltage breakdown characteristics of the concentric line are good enough for practical application. Consider the X-band case:

Taking $E = 25$kV/cm

$b/a = 2.09$

$\lambda_c = 2.80$cm

giving $a = 0.29$cm and $b = 0.61$cm

from (2.3) $W = 62.5 \times 10^7 \times 0.084 \times 0.738/120$

$W = 323$kW

It is, therefore, practicable to use such a rotating joint at X-band for powers in the 200kW region, and powers in the 1,000kW region may be used without excessive pressurizing.

THE CONCENTRIC LINE-TO-WAVEGUIDE TRANSITION

To allow for rotation, it is necessary that the transition at one end of the joint shall be of a symmetrical design; the dimensions of crossbar and similar couplings are too small, even at S-band, to give enough room for a half-wave choke. It is convenient in some cases to use a crossbar coupling at the fixed end of the joint, as it is not difficult to obtain a good match over a broad band with this transformer. A simple probe or a probe with some form of knob on the end is a good transformer when

* *Royal Naval Scientific Service.*

bandwidths up to about 7 per cent are required. For greater bandwidths and for high powers the doorknob coupling has proved the best transformer. As the inner conductor passes right across the waveguide into the doorknob, a second concentric line channel may be run inside the first. This channel will only be suitable for low powers. An S-band joint with three such subsidiary low-power channels in addition to the high-power channel has been designed. The dimensions of an X-band line make it difficult to use more than one such low-power channel, unless very low-impedance lines are used and it is difficult to design a good transition for a very low-impedance line.

The hemispherical doorknob, which is usually used, will not give a good match between a 44 ohm line and standard waveguide over a broad band and it is necessary to use a matching diaphragm. A truncated cone shape will give a good match over a 10 per cent band, and a rotating joint using this transformer has been developed giving a match of about 0.9 over a 10 per cent band at X-band. The most critical dimension of this form of doorknob is the height, but the optimum height is nearly the same for a wide range of top and bottom diameters. The correct procedure for determining the doorknob parameters is therefore to begin by finding the height. A truncated cone should be made with the bottom diameter about 0.9 times the waveguide width and with a semi-angle of about 25°. The height should be about 0.7 times the waveguide height. The height of the doorknob should then be reduced in small steps until the optimum is found, the waveguide piston being adjusted to the best position in each case. The aim from the start should be a good match over the required band, not a spot-frequency match. The optimum diameters should then be found, leaving the height fixed at the value just determined. A final adjustment of height is advisable after the diameters have been fixed. It will be found that a semi-circular piston gives much better broad-band characteristics than a flat piston.

If some form of supporting bead or spacer is required in the concentric line, a half-wave spacer close to the transition is as good as any other type and is the simplest to design. The spacer should be left in place throughout the determination of the doorknob parameters, and varying the length and/or the position of the spacer will provide a convenient final fine adjustment of match. Fluon is the best material known at present for the spacer. The dielectric constant is 2.0, there is no surface tracking with its attendant permanent damage, and the material may be used up to at least 200° C. It is easily machined. The power factor is very low (less than 0.002), and the dielectric strength is between 1,000 and 2,000volts/mil. Distrene may be used, but is liable to soften at the working temperature of the rotating joint. The losses in perspex are high enough to cause melting in a high-power line, but it is a convenient material to use in a low-power line of very small dimensions due to its strength. Metal-to-glass sealed beads are not very satisfactory, owing to the possibility of breakage. Wherever possible, the joint should be designed with no line supports. A short joint with a 6mm-diameter inner conductor fixed at one end is a sound mechanical design.

A concentric line/radial waveguide half-wave choke should be used at the doorknob. At X-band, the concentric line quarter wavelength will penetrate beyond the bottom of the doorknob; at S-band this may not be so, but the doorknob will be large enough to allow room for the radial waveguide-quarter-wavelength in its base. Fig. 8 shows one end of a two-channel concentric line joint.

The Crossbar Transition

The optimum concentric-line characteristic impedance for a broad-band transformer is between 70 ohms and 80 ohms, but a good transformer can be made with a 40 ohm line.

The effect of varying the diameter of the rod connecting the inner conductor to the crossbar is small, and it is convenient to make this equal to the inner-conductor diameter. The position of the crossbar is critical; the diameter of the crossbar is also critical but the optimum diameter remains sensibly constant for different crossbar positions. The correct procedure is therefore to find the optimum diameter at one position (say at the centre of the waveguide) and then to find the best position.

The Probe Transition

There is much information available concerning this transformer, which is easy to optimize. It should be noted that a semi-circular piston is again helpful in obtaining good broad-band characteristics. The probe terminating in a sphere does not give an appreciable improvement in match, but is useful for reducing voltage breakdown.

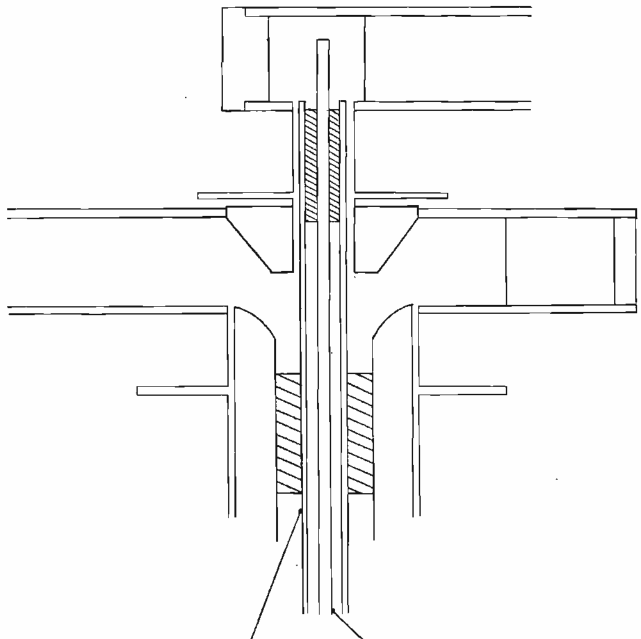


Fig. 8. Doorknob and probe transitions

Other Transitions

The earliest type of transformer is the "crossed transition" with concentric-line stub. The inner conductor is carried across the waveguide into a concentric line stub which is of the same dimensions as the concentric line entering the waveguide. The transformer is tuned with a waveguide piston and the stub. This is a narrow band transformer with a tendency to voltage breakdown at the open stub, but is a useful tunable device for laboratory use.

Most of the other known transitions are discussed in "Microwave Transmission Circuits", Vol. 9 of the Radiation Laboratory Series, but they are of little interest in this context. They are all more or less narrow-band and have no special advantages except perhaps the E-plane loop coupling for feeding the concentric line into the end of the waveguide.

Finally, there is a suggested form of transformer, based on the bi-conical dipole, which might become a useful broad-band coupling and which lends itself to concentric line rotating joints. Unfortunately, this transformer has received very little attention. There is much information available on broad-banding the bi-conical dipole aerial, and there seems to be no reason why such an aerial in a waveguide, backed by a semi-circular piston, should not exhibit broad-band characteristics. The most suitable form of this aerial would be that fed along the cone

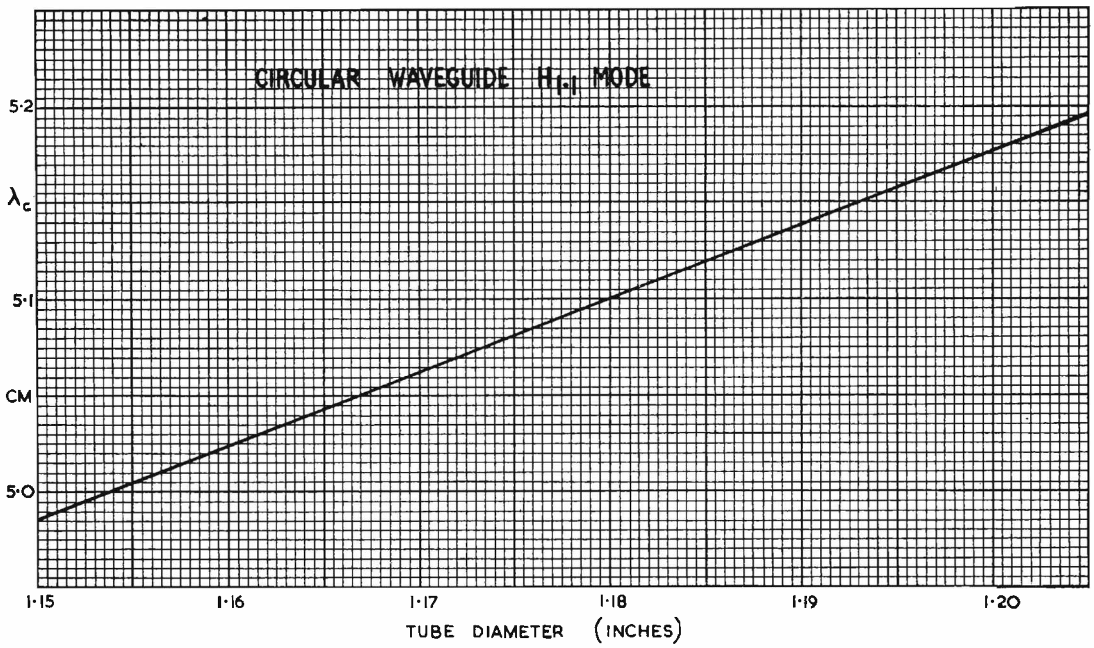


Fig. 9. Cut-off wavelength against tube diameter

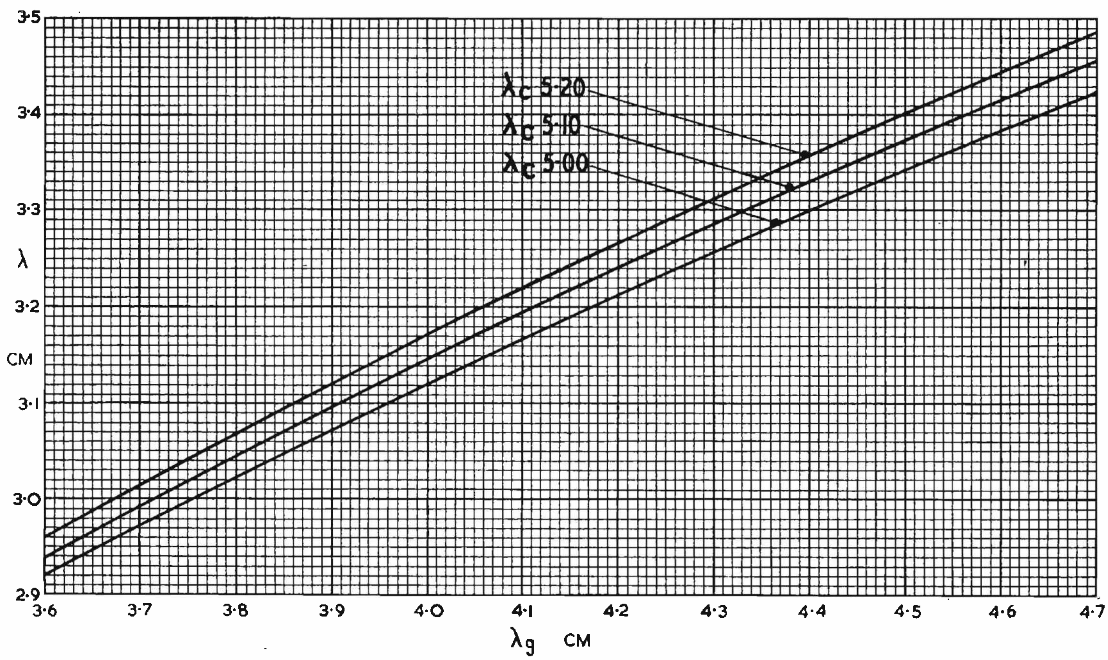


Fig. 10. Free space to guide wavelength

axes, the inner conductor of the concentric line passing through a hole in that cone which is connected to the outer conductor. The diameter of this hole should be the same as the diameter of the outer conductor, when no serious voltage breakdown difficulties should be experienced.

The Slip-Ring Rotating Joint

A form of joint that is useful when a large diameter is necessary and a full 360° rotation is not required is the waveguide slip-ring. A length of rectangular waveguide is bent into a complete circle, in either the E or H plane. The waveguide is broken along the centre of each broad side, with suitable half wave chokes. Rectangular waveguide is fed into each unbroken side, a metal block of half the waveguide depth being fixed in the waveguide by the feed point so as to form a 90° corner. Power fed in through one waveguide will travel around the circular section to the other corner. If the blocks are made to extend a long way behind the "corner", very little power will travel back in that direction. A better method is to extend the block across the other half of the waveguide in a series of strips, like a comb. The strips on one block corresponding to the spaces in the other comb. The electrical length of the joint varies on rotation, but a very good match can be obtained. In the case of an aerial required to scan nearly all round a large mast, the mast can pass up the centre of the slip-ring.

Conclusions

The major problem in the design of rotating joints is one of bandwidth, especially when a long joint is required. Voltage breakdown is also a serious problem at X-band,

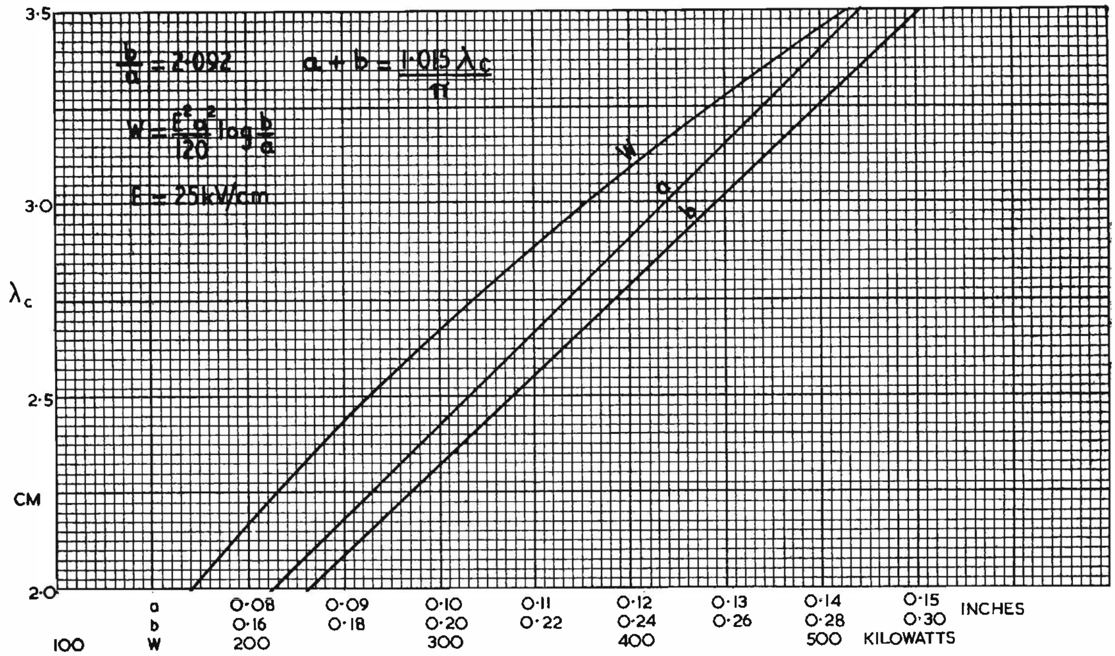


Fig. 11. Optimized concentric lines

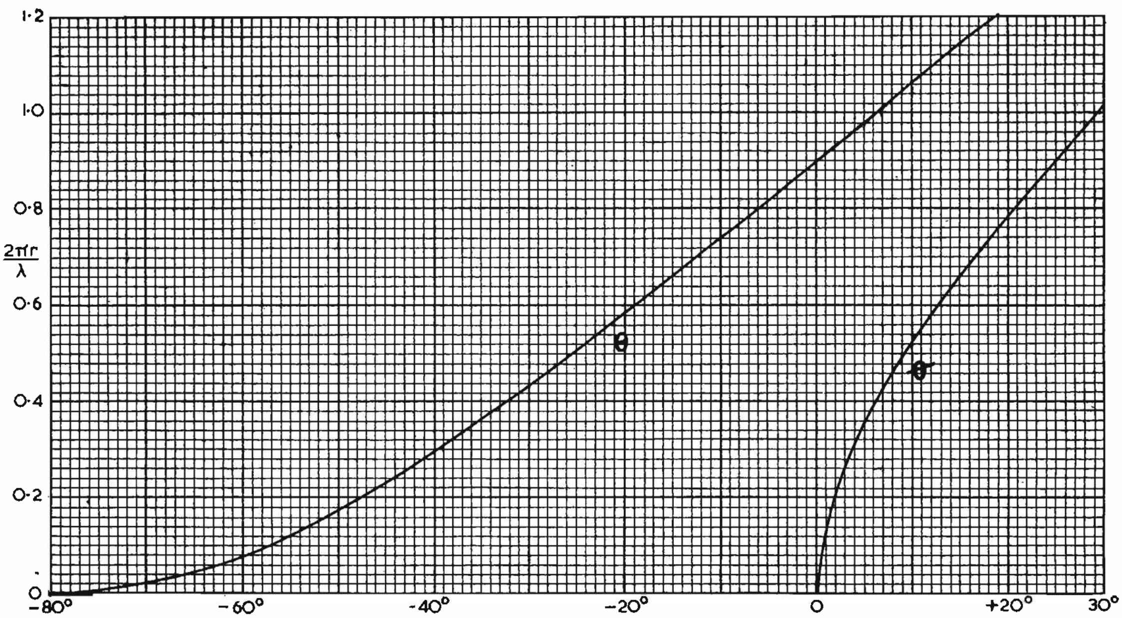


Fig. 12. Hankel functions-phase

the safe operating power level for all rotating joints being less than that for standard waveguides. The concentric-line rotating joints are the simplest, most compact and easiest to design of all the types described. They are free of resonance problems and can be very broad-band. The power handling properties are adequate for most purposes. The doorknob transformer lends itself well to rotating joint applications, and a truncated cone shape of doorknob used with a semi-circular piston gives good broad-band properties without the use of matching irises. A form of circular waveguide rotating joint using resonant-ring $H_{1,1}$-mode suppressors and $H_{1,1}$-mode absorbing cavities is free of resonances, but is less compact than the concentric-line joint, requires closer manufacturing tolerances and is more susceptible to voltage breakdown.

Acknowledgment

This article is published with the approval of the Lords Commissioners of the Admiralty, but the responsibility for any statements of fact or opinions expressed rests solely with the author.

BIBLIOGRAPHY

Ramo, Whinnery. *Fields and Waves in Modern Radio* (J. Wiley & Sons : Chapman & Hall). "Radial Transmission Lines."

Principles of Microwave Circuits (Rad. Lab. Series No. 8 : McGraw-Hill). "Radial Transmission Lines. Higher Modes in Concentric Lines. Resonance in a Closed Circular Guide."

Microwave Transmission Circuits (Rad. Lab. Series No. 9 : McGraw-Hill.) "Rotating Joints."

Huxley. *Waveguides* (Cambridge Univ. Press). "Circular Waveguides and Higher Modes in Coaxial Transmission Lines. E_{01}-H_{01} Transformers and Rotating Joints. Junctions of Circular with Rectangular Waveguide."

Schelkunoff. *Electromagnetic Waves* (D. Van Nostrand). "Sections 8,8 : 8,9 : 10,17, Wave Propagation along Coaxial Cylinders.

Slater. *Microwave Transmission* (McGraw-Hill). "Crossed Transition. Aerials in Waveguides."

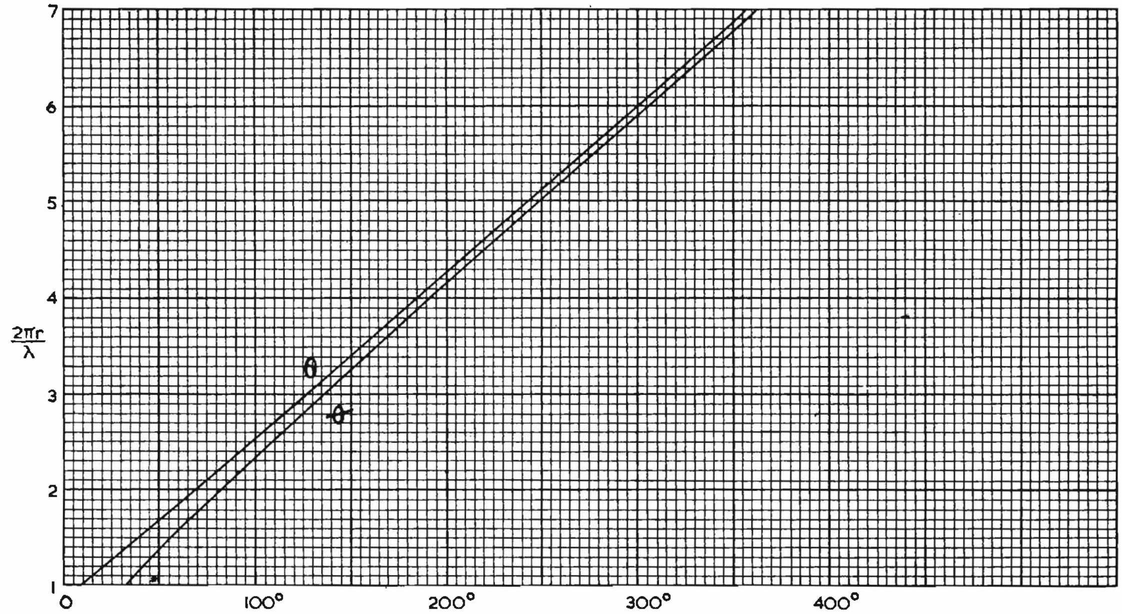


Fig. 13. Hankel functions-phase

APPENDIX

TABLE OF λ_c/λ AGAINST λ_g/λ

This table is calculated from $\lambda_g/\lambda = 1/\sqrt{1-\lambda^2/\lambda_c^2}$

λ_c/λ	λ_g/λ	diff.	λ_c/λ	λ_g/λ	diff.
					0.039
1.010	7.128	2.052	1.500	1.342	0.033
1.020	5.076	0.901	1.550	1.309	0.028
1.030	4.175	0.536			
1.040	3.639	0.359	1.600	1.281	0.024
1.050	3.280	0.880	1.650	1.257	0.020
1.100	2.400	0.375	1.700	1.237	0.018
1.150	2.025	0.216	1.750	1.219	0.016
1.200	1.809	0.142	1.800	1.203	0.014
1.250	1.667	0.102	1.850	1.189	0.013
1.300	1.565	0.076	1.900	1.176	0.011
1.350	1.489	0.060	1.950	1.165	0.010
1.400	1.429	0.048	2.000	1.155	
1.450	1.381	0.039			

For convenience in calculating $H_{1\cdot1}$ mode resonances in circular waveguides, Figs. 9 and 10 have been prepared. Fig. 9 gives cut-off wavelength against tube diameter (in inches) for the $H_{1\cdot1}$ mode and covers the range normally used at X-band. Fig. 10 gives free space wavelength against guide wavelength for three cut-off wavelengths. This also covers the normal X-band range.

Cut-off wavelength for $E_{0\cdot1}$ mode $= 2.61a$

Cut-off wavelength for $H_{1\cdot1}$ mode $= 3.41a$

where a = tube radius.

Concentric Lines

Fig. 11 gives data for optimized concentric lines.

The curves are calculated from $b/a = 2.092$ ...... (2.8)

$$a + b = 1.015\lambda_c/\pi \quad (2.1)$$

$$W = E^2a^2/120 \log_e b/a \quad (2.3)$$

E is taken as 25kV/cm.

Radial Waveguides for Chokes

Some form of half-wave choke is required in most rotating joints, and this usually consists of a quarter wavelength of concentric line and a quarter wavelength of radial waveguide. We are interested in two special cases of a radial waveguide fed at a radius r_i with the waveguide travelling outwards from the point of feed. We require either an infinite input impedance when the output is short circuited or zero input impedance when the output is open circuited. We normally know the inner radius r_i and wish to determine the outer radius r_o.

The input impedance of a radial waveguide has been calculated by Ramo and Whinnery (Fields and Waves in Modern Radio) and is also discussed by Marcuvitz (Principles of Microwave Circuits, Vol. 8 of the Radiation Laboratory series). The special cases reduce to:

Input impedance when output is short circuited is given by:

$$Z = jZ_0 \frac{\sin(\theta_i - \theta_o)}{\cos(\phi_i - \theta_o)} \quad (A.1)$$

Input impedance when output is open circuited is given by:

$$Z = -jZ_0 \frac{\cos(\theta_i - \phi_o)}{\sin(\phi_i - \phi_o)} \quad (A.2)$$

where the subscripts i and o refer to input and output, and θ and ϕ are the phase angles of the Hankel functions $H_0(2\pi r/\lambda)$ and $jH_1(2\pi r/\lambda)$ respectively.

For Z in (A.1) to be infinite,

$$\phi_i - \theta_o = \pi/2 \quad (A.3)$$

For Z in (A.2) to be zero,

$$\theta_i - \phi_o = \pi/2 \quad (A.4)$$

Figs. 12 and 13 give θ and ϕ plotted against $2\pi r/\lambda$.

The zero and first order Hankel functions may be written as:

$$H_0(kr) = J_0(kr) \pm jN_0(kr)$$

$$H_1(kr) = J_1(kr) \pm jN_1(kr)$$

$$\text{or } jH_1(kr) = \mp N_1(kr) + jJ_1(kr)$$

The phase angles θ and ϕ of the Hankel functions $H_0(kr)$ and $jH_1(kr)$ are defined by:

$$\tan\theta = N_0(kr)/J_0(kr)$$

$$\tan\phi = J_1(kr)/-N_1(kr)$$

k is the propagation constant which is equal to $2\pi/\lambda$ for the mode considered.

The Hammond Organ

By Alan Douglas

ALTHOUGH this instrument is known and used throughout the world, it was not the first application of electromagnetic tone generators. The ingenuity shown in the generator design is mechanical, and it seems reasonable to state that it was only the experience of Mr. Laurens Hammond as a clock maker which made it possible to produce a gear-driven unit of such outstanding consistency and reliability. The seeming simplicity of the mechanical drive is extremely deceptive, so much so that it has defeated all efforts by other makers to produce a gear-driven generator.

The electromagnetic system used was first designed and actually made by Thaddeus Cahill[1] between 1897 and 1903. The perseverance of this investigator against incredible odds has never been properly recognised. With no valves or amplifying gear to help him, Cahill set up a complete organ with full harmonic synthesis, signals from which were audible on head telephones. Something over 1,000 cubic feet was required to house this massive generator, and it was intended to form a company to distribute music on rental over telephone lines; but the negotiations failed, and the scheme was abandoned.

Dr. Cahill fully appreciated all the requirements for harmonic mixing as now practised by Hammond, and this again underlines the difficulties so often encountered by the early investigators—lack of means properly to interpret their ideas.

The Hammond organ contravenes all musical concepts in its design and performance; but it is not necessary to go into this here, or the costly legislation in which Hammond was involved in the U.S. in his efforts to establish the right to call it an organ. One very important fact should, however, be noted. When Hammond launched the instrument on the market, he said: "While the Hammond is played like a pipe organ, it is not made in imitation of one; it is a new musical instrument with a voice of its own." If this statement is clearly borne in mind, no further discussion on its organesque qualities need arise.

Many different models of the Hammond are made, but as might be expected, in the new types there is an increasing tendency to improve the overall effect. Consequently it is thought that the latest developments in design would be of interest, as none of these are available in this country for demonstration.

Principle of Tone Generation

Additive synthesis is employed, based on the generation of a series of fundamental frequencies by rotating iron alternators. Musical tones requiring a complex structure are obtained by borrowing frequencies from the fundamental set and mixing them together at the required levels.

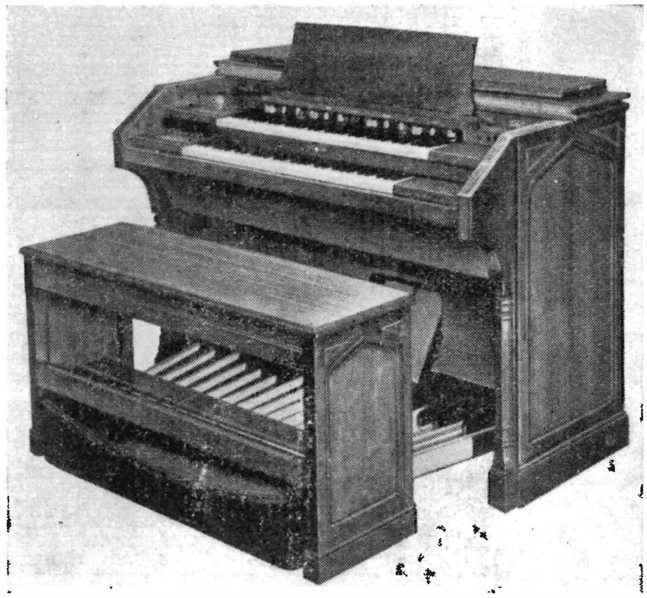


Fig. 1. The console

MAIN GENERATOR.

This consists of 91 iron disks driven in pairs from a common shaft, and disposed on either side of the shaft for compactness. The wheels are geared together so that an approximation to the equally tempered scale is obtained. The tuning accuracy is about 2½ parts in a million of the desired frequency for each group of wheels and is, of course, permanent. Each wheel is so contoured that an approximately sinusoidal waveform is generated, but it is indeed an approximation and a good deal of subsequent electrical treatment is required to get even a workable waveform.

The wheels are roughly 1.8in. diameter and 1/16in. thick. They are produced in batches and subsequently carefully heat-treated. The slightest variation in the physical or metallurgical constants of a wheel will render it useless. There are a good many machining "tricks" in producing these wheels, and the net effect of all these points is that it is extremely difficult for an amateur to copy them. In order to offset magnetic leakage and to preserve dynamic balance, wheels are mounted in octave relationship in the various groups. In some cases a dummy wheel is used to assist balance. Fig. 3 shows the drive system for any one set of wheels. The main shaft, which is in sections for ease of assembly, carries the 12 brass wheels. The thin bakelite wheel is driven from this, and then transmits the required torque to the tone wheels solely through the helical spring. Normally this assembly rotates as one, but if there should be any gear tooth ripple, or if a particle of rust should lodge in the pickup gap, then the springs operate and the tone wheels slip.

The evolution of this seemingly simple drive represents a vast number of experiments. It is a tribute to the sound design that after more than ten years of operation, gear tooth ripple due to inevitable wear is not detectable on old instruments.

Adjacent to each wheel is the signal coil and magnet. This latter is of very small power, for a number of reasons, and has one end reduced to a chisel point. The gap between this end and the tone wheel averages 0.005in. The signal coil is wound on a bobbin near to the chisel end. These coils are of an average impedance of 15 ohms; as an example of the windings, the A = 440c/s coil has 1,500 turns of 40 B & S enamel. The lower frequency coils are fairly large to give sufficient output.

The coil end of the magnet is braced against vibration,

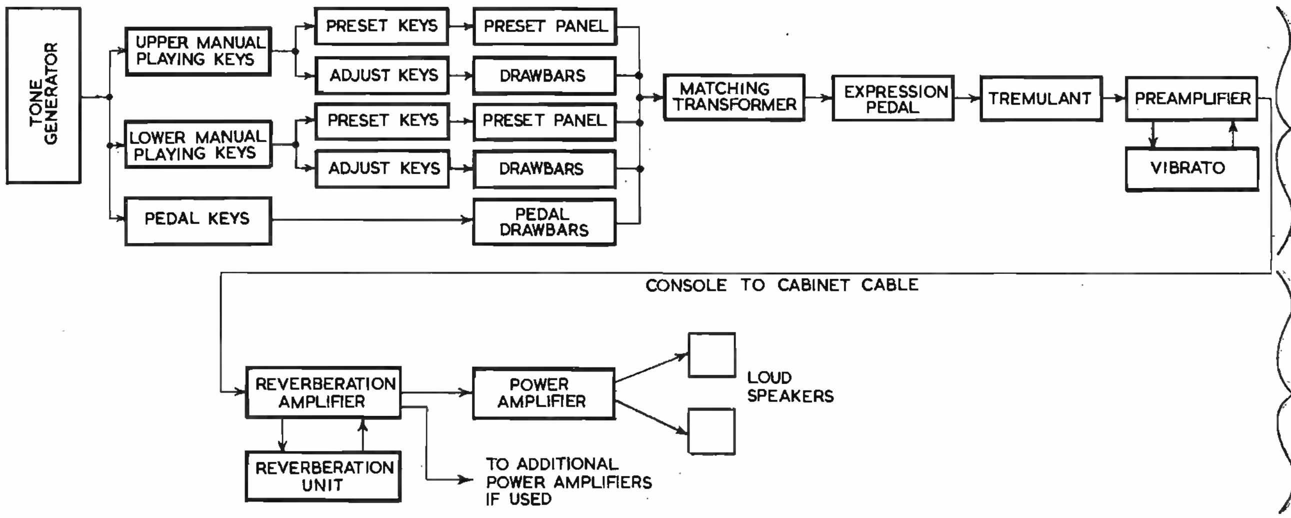


Fig. 2. Block schematic of the Hammond organ

and the signal level is adjusted by increasing or decreasing the air-gap. Magnets for the higher frequency coils are reduced in width to minimize fringing, as the tone wheel "teeth" are extremely small on these wheels. Many magnetic difficulties exist in this type of generator, which are analysed in detail elsewhere.[2] It is clearly necessary, to keep within practical bounds, to reduce the different gears and spindle speeds to a minimum. For this reason the tone wheels have the following numbers of teeth; 2, 4, 8, 16, 32, 64, 128 and 192. An assembly with a 2 tooth wheel has also a 32 tooth wheel; 4 is coupled with 64; 8 with 128; the twelve 16 tooth wheels are mounted with seven 192 tooth wheels and five blank wheels. Sheet steel screens are interposed between each set of four tonewheels.

The main generator is driven from a small synchronous motor through a heavy flywheel and torsion spring. To start this motor, a shaded pole induction motor runs the generator up to nearly synchronous speed, and is then thrown out of engagement by a Bendix type of pinion—exactly like a car self-starter.

In an instrument of this kind, maintenance has to be reduced to a minimum. To ensure adequate lubrication of the many bearings, these are made from oil-retaining or porous bronze, all connected to a trough at the top of the generator case. Capillary action keeps oil constantly in the bearings through the cotton wicks with which they are connected to the trough.

The lower frequency coils are fitted with copper rings for reducing harmonic distortion. The eddy current loss is low for the fundamental frequencies but high for the harmonics. Transformers are used on notes 44 to 48, and tuned transformers, which resonate at the fundamental frequencies of these coils, on notes 49 to 91. These tend to emphasize the required frequencies and suppress harmonics.

Ninety-one independent frequencies are produced by

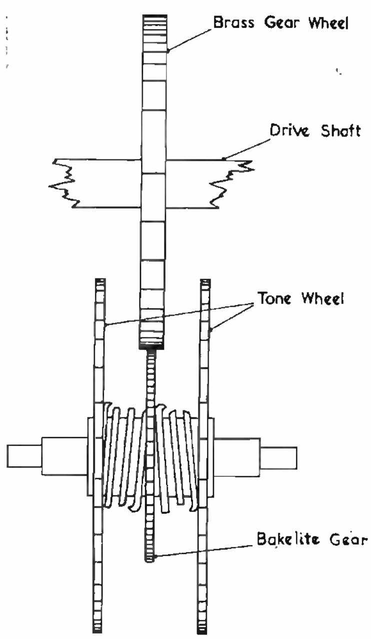


Fig. 3. Tone wheel drive

Fig. 4. Frequency Table

Fundamental A = 55 c/s.

Harmonic	Natural Frequency	Nearest Note, E.T.S.	Frequency E.T.S.	Deviation C/S	Percentage Error
1	55	A^1	55	0	0
2	110	A^2	110	0	0
3	165	E^3	164.81	− 0.19	0.115
4	220	A^3	220	0	0
5	275	$G\#^4$	277.18	+ 1.82	0.662
6	330	E^4	329.63	− 0.37	0.112
7	385	G^4	392	+ 7	1.820
8	440	A^4	440	0	0
9	495	B^4	493.88	− 1.12	0.226
10	550	$C\#^5$	554.37	+ 4.37	0.795
11	605	$D\#^5$	622.25	+17.75	2.935
12	660	E^5	659.26	− 0.74	0.112
13	715	F^5	698.46	−16.54	2.320
14	770	G^5	783.99	+13.99	1.820
15	825	$G\#^5$	830.61	+ 5.61	0.680
16	880	A^5	880	0	0
17	935	$A\#^5$	932.33	− 2.67	0.286
18	990	B^5	987.77	− 2.23	0.226
19	1045	C^6	1046.50	+ 1.50	0.147
20	1100	C^6	1108.73	+ 8.73	0.793
21	1155	$C\#^6$	1174.66	+19.66	1.700
22	1210	D^6	1244.51	+34.51	2.850
23	1265	$D\#^6$	1244.51	−20.49	1.620
24	1320	E^6	1318.51	− 1.49	0.113
25	1375	F^6	1396.91	+21.91	1.159
26	1430	F^6	1396.91	−33.09	2.380
27	1485	$F\#^6$	1479.98	− 5.02	0.338
28	1540	G^6	1567.98	+27.02	1.815
29	1595	G^6	1567.98	−27.02	1.760
30	1650	$G\#^6$	1661.22	+11.22	0.681
31	1705	$G\#^6$	1661.22	−33.78	1.980
32	1760	A^6	1760	0	0

this generator, which has remained practically unaltered since 1935.

Pedal Generator

The Hammond has long been criticized for its pedal department. Previous models provided only a fundamental and octave at a variety of levels, and with certain other shortcomings in the instrument, the lack of harmonics was painfully apparent. The new instrument has a separate tone wheel generator with disks profiled to provide a series of odd harmonics for each note. To extend possible synthesis, the pedal key switches are so connected to the manual 91 note generator that even harmonics may be borrowed therefrom. The complex tone wheels supply the fundamental, 3rd, 5th, 7th, 9th, and 11th harmonics. Several fixed tone colours are available by means of toe pistons. Indicators are provided to show which piston is in circuit, since of course these latter are not visible from above the keyboards. These additional circuit elements provide a number of 16ft pitches which have depth and character, and in association with the new loudspeaker system provide a really useful bass.

Fig. 5. Example of synthesised organ tones. (transformer tappings).

	sub f	sub 3rd	f	2	3	4	5	6	8
Open diapason	0	0	6	6	4	0	0	0	0
Flute	0	0	4	3	2	0	0	0	0
Clarinet ..	0	0	6	2	7	0	5	2	0
Trumpet ..	0	0	5	7	7	8	7	4	0
Gamba	0	0	4	6	4	5	3	2	0
Great to 15th (i.e., full organ without reeds) ..	5	0	8	8	7	5	4	3	5

Playing Keys and "Stops"

To cause an instrument of this type to operate, it is necessary to feed as many frequencies as will ever be required to synthesize a tone, into each playing key. For this purpose, every playing key operates a vertical bank of nine contacts, which are depressed to meet nine horizontal busbars. The contacts are tipped with palladium alloy and are divided as in a post office relay. Each busbar is hexagonal in section and runs the full length of the keyboard; it may be rotated by a coin slot at one end to bring a new contact face into use.

The usual practice with both electronic and pipe organs is to designate each note or generator by a number, e.g., CC (lowest note of keyboard) = 1; middle C = 25, and so on. This makes it easier to follow wiring diagrams. So in the case of the lowest manual key, the generators connected to its contacts must supply the sub-fundamental, sub-third; fundamental, 2nd, 3rd, 4th, 5th, 6th, and 8th harmonics. Accordingly, generator coils numbers 1, 8, 13, 25, 32, 37, 41, 44 and 49 are connected. Note that signal coil No. 1 is not manual note CC, but the octave below it, of 16ft pitch.

This sequence of wiring is continued, the same generator being paralleled to both keyboards, as far as possible; but it is found that after a time there are not enough generators to complete all the upper harmonics for the higher notes. It is always difficult to decide how far to extend any generator system, but in general this is related to the fidelity of tone desired. Since the fidelity of the Hammond to known tone colours is very poor, though it can produce a wide range of characteristic sounds of its own, the generators available must be regarded as adequate. The fundamental frequency range is from 32.703 to 5919.904c/s.

We now see that the depression of any playing key would connect a series of frequency sources to its appropriate busbar, so that from the nine busbars all available frequency can be collected. The next step is to select groups of frequencies which when simultaneously combined will produce a musical sound.

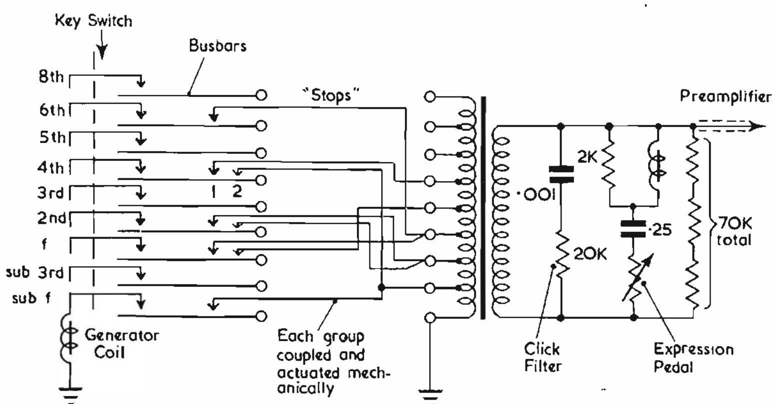


Fig. 6. Switching arrangements for one note

If the busbars were connected to nine switches, the outlets from which could be paralleled, then any combination from the generators available could be passed to the amplifiers. The "stops" of this instrument take the form of multi-contact switches, having as many contacts as represent the required tone colour. It is quite clear that if there are only 9 harmonics available, and if the sub-fundamental and sub-third are infrequently required, then only a narrow range of tonal contrasts is available. Nevertheless, by judicious use of the resources available a good many simple tones can be reasonably well synthesized.

A glance at the table, Fig. 4, will show how limited are the combinational powers of equally tempered generators. Distortion of an intolerable nature will be produced if anything beyond the 12th is used. For odd harmonics the case is even worse. Those who are familiar with pipe organ waveforms will realize the difficulties in selecting suitable tone colours for synthesis.

Having switched the required number of generators for some sound, it is then necessary to combine them at the required loudness levels. This is done by a similar arrangement of switches which transfer the selected frequencies to a transformer with tapped primary. The nine tappings are a mechanical convenience to match the keying system,

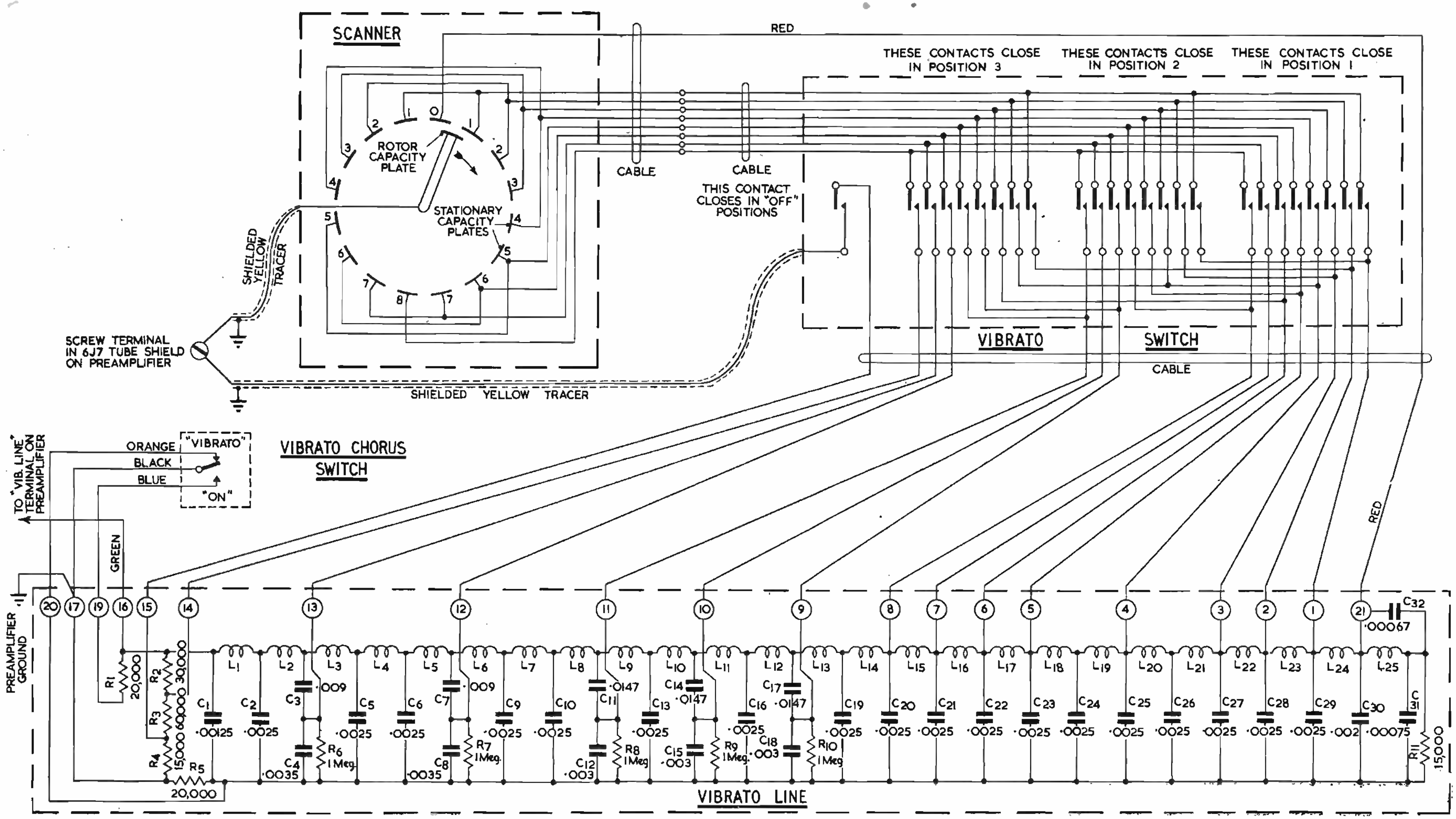


Fig. 7. Schematic of vibrato system

and each tapping gives roughly twice the *loudness* of the previous one. To make synthesis easy, Hammond supplies a chart of some 40 tone colours, and in order to set these up, it is only necessary to connect the correct busbar to the correct switch for the transformer tapping. The earthed end of the winding is designated as O. (minimum volume). A few examples are appended in Fig. 5. Fig. 6 shows the switching layout for one note, and clearly illustrates all the above points.

Opinion is divided as to whether the extremely abrupt attack due to keying into the actual signal circuits is a virtue or otherwise; certainly it immediately identifies this instrument. There is no question that for certain purposes this is a valuable feature; equally, it is disadvantageous for executing other types of music. Even where the most rapid attack is required, however, there are keying transients which are usually of a clicking nature in the upper register, and of a thumping character in the bass. It is of course very difficult to secure simultaneous closing of nine key contacts, and much ingenuity has been expended on the touch mechanism. All the same, transients do appear and they are substantially removed by the filter shown in Fig. 6. This naturally reduces the high-frequency response. In order to obtain a range of expression, a potentiometer is connected across the transformer secondary, operated by a balanced swell pedal. The rapidity and range of dynamic expression makes many interesting effects possible with this instrument.

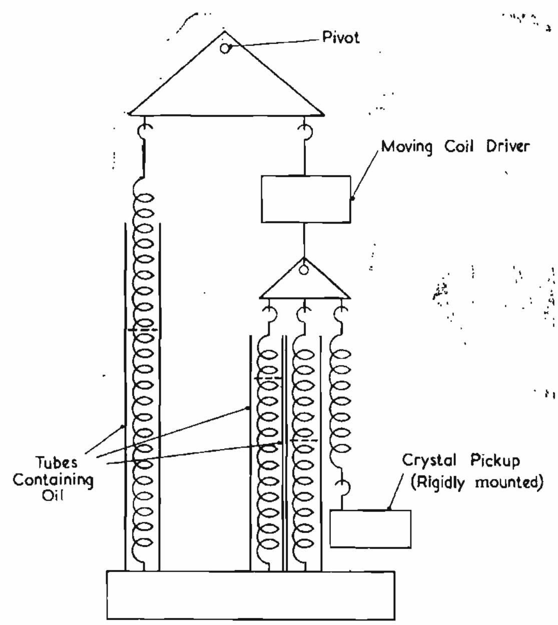


Fig. 8. Principle of reverberation device

From the mixing transformer, the signal is split and this leads to the most interesting electrical features of the Hammond.

Original Chorus Generator

It was very soon found that the signals from the main generator alone were not capable of producing sufficiently intricate musical waveforms. In consequnce, an additional generator was provided, having a limited number of extra tonewheels tuned slightly sharp and slightly flat to the main wheels. The frequencies covered are numbers 56 to 91. The difference in pitch is 0.8 per cent for wheels 56 to 67, and 0.4 per cent for wheels 68 to 91. The signals from this generator could be superimposed on the main generator, and the coils combined in the same way through the key contacts. By this means, a very large number of beating effects could be set up, which provided an added subtlety to the tone, especially in quieter registrations.

All sustained tone instruments benefit from the judicious use of a tremulant or vibrato. A pipe organ has both frequency and amplitude modulation, but in earlier Hammonds it was only possible to vary the amplitude in a cyclic fashion by a motor-driven cam which opened and closed a variable resistor chain across the transformer.

Now there are several things wrong with the chorus generator and vibrato concept. Firstly, not enough additional frequencies are supplied by this generator; secondly, the tuning of these intervals is fixed in the same relationship to the main generator tones; thirdly, the relative amplitudes are not separately controllable. With regard to the vibrato, while the overall rate of change was adjustable on some models, amplitude variation alone never sounds right; and the rate, once fixed, applied equally to all frequencies. These units were abolished in favour of more satisfactory methods.

Line Delay Vibrato [3]

In order to simulate the effect in an orchestra, wherein the instruments of higher pitch use a faster rate of vibrato than those of lower pitch, the new vibrato equipment varies

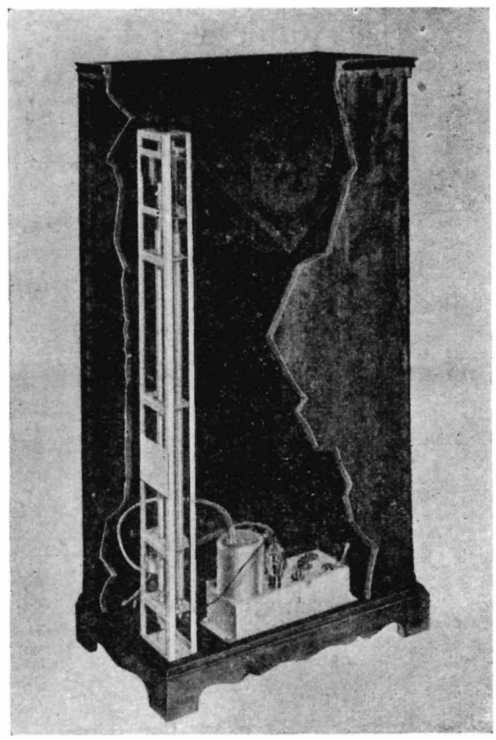


Fig. 9. The electro-mechanical transducer fitted in the loudspeaker cabinet

the frequency of all tones by continuously shifting their phase by means of an electrical time delay line, composed of a number of filter sections, and a motor-driven capacity scanner which sweeps back and forth along the line.

Electrical waves fed into the line are shifted in phase by each line section (the amount per section being proportional to frequency), so that at any tapping on the line, the phase is retarded relative to the previous tapping. The scanner sweeping the line will thus encounter waves increasingly retarded in phase at each successive tapping. As a shift in phase is equivalent to an instantaneous change in frequency, the continuous phase change becomes a continuous frequency variation. As the scanner sweeps from one end of the line to the other, and back, it alternately

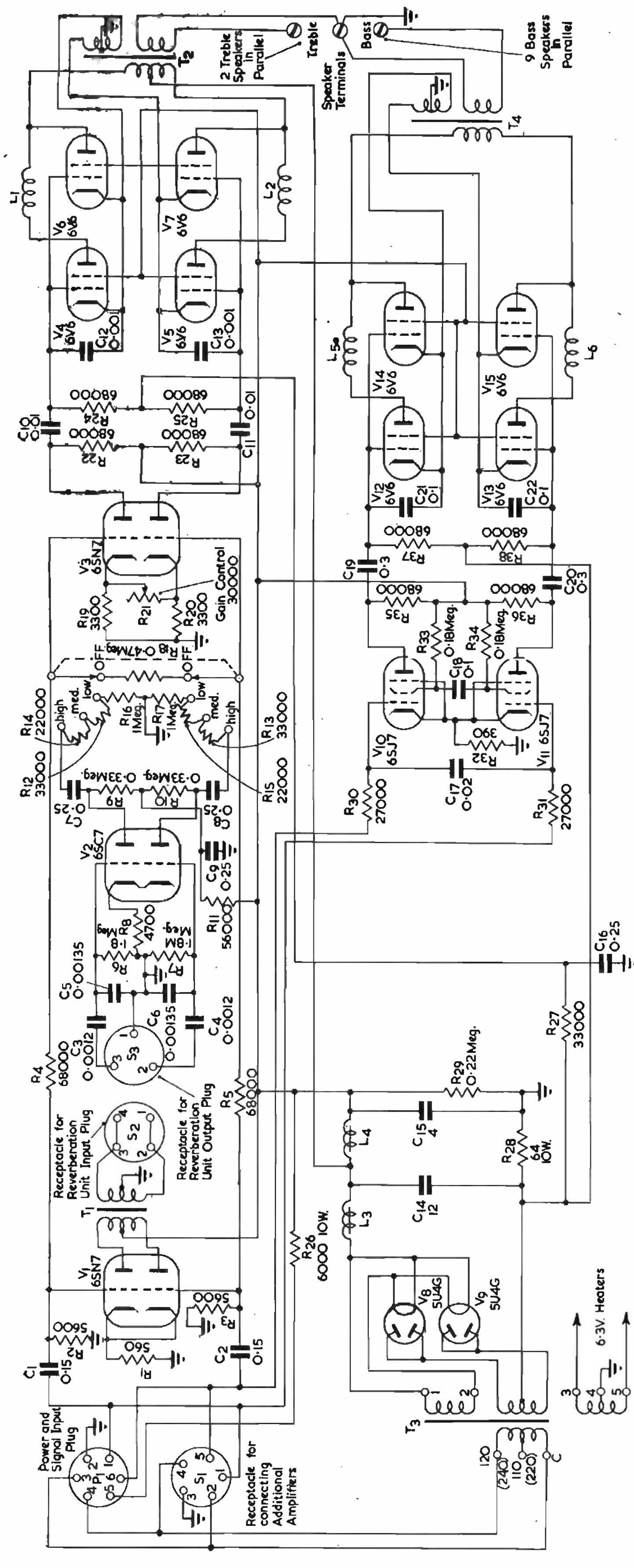


Fig. 10. The latest amplifier circuit

raises and lowers the output frequency, the average remaining equal to the input frequency. The exact amount of frequency shift depends not only on the amount of phase shift in the line but on the rate of scan. This is fixed, because the scanner is driven at 412 R.P.M. by the main generator motor.

The degree of vibrato is varied by a switch which allows the whole line to be scanned for a deep vibrato; half of it for a smaller vibrato, and one-fourth for lesser effects. A chorus effect, similar but superior to that previously produced by the chorus generator, is obtained when the vibrato output signal is mixed with a part of the signal without vibrato. The scanning unit is a 16 pole variable capacitor, the rotor of which meshes with all the poles in sequence. The complete circuit is shown in Fig. 7.

Artificial Reverberation Unit[4]

It is superfluous to mention that no organ-like instrument of any kind sounds well in an acoustically "dead" enclosure. No sense of majesty or grandeur of tone can be obtained without reverbration. Whilst the siting of a pipe organ is a matter for the utmost care and consideration, an electronic instrument of this type will frequently be used in the most unsuitable surroundings. The effect is worsened by the fact that the Hammond does not produce tones having gradual decay intensity envelopes. In these circumstances, a method for producing artificial reverberation has been applied, which can be effective; but the presence of standing waves and powerful natural resonances can defeat the correct functioning of this device in small rooms.

Accordingly, the input signal, after some pre-amplification, is split. Part of it passes to the main amplifier, and part to an electro-mechanical transducer designed to both delay and reflect the signal through a series of long coil springs, until it eventually reaches a crystal pickup which transfers it to the main amplifier where it is mixed with the steady signal. Fig. 8 shows the device in essence, and Fig. 9, shows its relatively small size, the loudspeaker cabinet here being about 52 in. high.

There are five carefully designed springs, four of which are damped in oil baths. The rate of delay is adjusted by the tension and the damping, and can be made substantially uniform for most frequencies. It is true that this is a very difficult unit to set up, but if properly adjusted both physically and for signal input level, quite remarkable results can be obtained.

New Amplifiers

The use of these auxiliaries calls for a more complex amplifying system, and Fig. 10 shows the latest circuit. In this, the treble channel feeds two 12 in. loudspeakers which face upwards (thus further reducing any key clicks); while the bass channel feeds nine 10in. cones all in parallel. This is a highly effective and economical way of getting good pedal response, though it calls for a rather exact design of output transformer, the speech coil load being only $^{8}/_{9}$ ohm.

To summarize, the latest Hammond provides:—

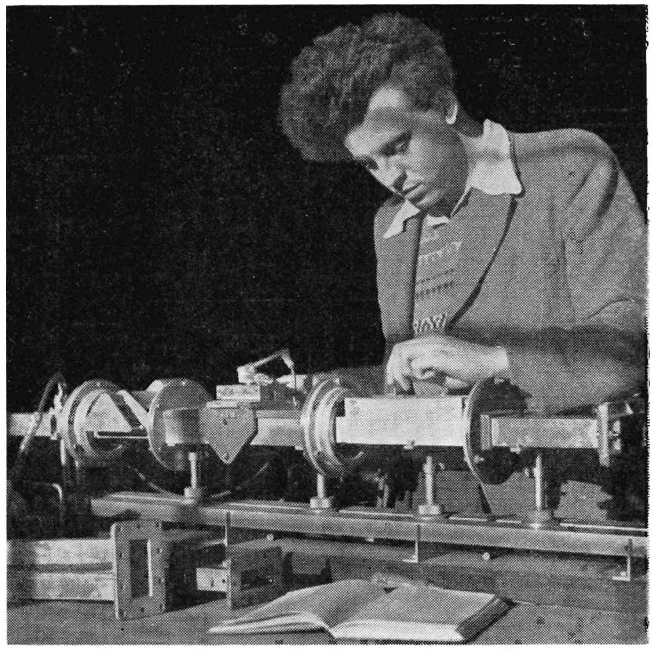
1. Harmonics up to the 12th.
2. Complex pedal tones.
3. A superior chorus effect.
4. A really effective vibrato.
5. Artificial reverberation.
6. Much better radiation of the bass frequencies.

REFERENCES

1 British Patents 8725 (1897); 3666A, B, C (1903).
2 Electronic Musical Instrument Manual (Pitman).
3 U.S. Patent 2,382,413.
4 U.S. Patent 2,230,836.

Supply Ministry Seeks Electronic Engineers

Research and Development Work for Graduates



Measurement of standing wave ratios for microwave equipment.

AN intensive drive to recruit electronic engineers for its research and development establishments is being carried out by the Ministry of Supply. Anxious in particular to attract young graduates, the Department has recently sent teams of its scientists to universities to explain to students the opportunities available in this and other fields.

Controlling the largest scientific organization in Britain, the Supply Ministry carries on a vast programme of research and development in almost every field of science at establishments throughout Britain and overseas. Some of this immense scientific effort—devoted primarily to the needs of the Fighting Services—is concentrated on electronics; radio and radar are two obvious examples of Service equipment which call for continuous research and elaborate facilities.

In addition, an increasing number of the Ministry's research establishments are introducing and devising electronic equipment to meet their own particular needs. Today, there is scarcely one which is not concerned to some extent with electronics research or electronics equipment.

Wide Choice

Consequently there is an urgent need for new staff—either for pure research or development work—who will have a very wide choice of opportunities in work of importance to the nation's future.

The establishments must build up a capital reserve of new information on which to base their future work, and this basic research into hitherto unexplored fields is a vital necessity calling for the highest resourcefulness and insight.

On the other hand, the investigation of new applications of the knowledge thus gained, and the detailed work of converting ideas into equipment capable of meeting the special and exacting demands of the Services, give very wide scope to the man who prefers development to "pure" research.

Team Work

Throughout the Ministry of Supply establishments there is active co-operation between engineers, physicists, mathematicians and other specialists. Mixed teams of scientists, indeed, are a striking and important feature of the Department's organization.

For the young scientist, in particular, this method of working is of the utmost value. It is a common-place to say that the electronics engineer is not born, but made. His skill is made up of natural aptitude, training and, above all, experience.

The young graduate working as a member of a team in a Ministry establishment, in constant contact with workers who have each received a specialized training in different fields, finds the continual interchange of ideas a stimulus which cannot be overrated.

Apart from good team work, however, the creative scientist requires full scope for his individuality and initiative. In the Ministry's own interests this fact is fully recognized; originality is welcomed and every encouragement is given to follow up new ideas which appear to hold promise.

Good care is taken to fit "square pegs" into "square holes," for it is clearly realized that enthusiasm lasts and increases best where interest lies and where training and experience can be given full play.

There is, naturally, the closest contact between Supply Ministry establishments, industry and university research centres. Taking them all in all, the facilities which the Ministry can offer are probably unrivalled elsewhere in the country.

Pay and Prospects

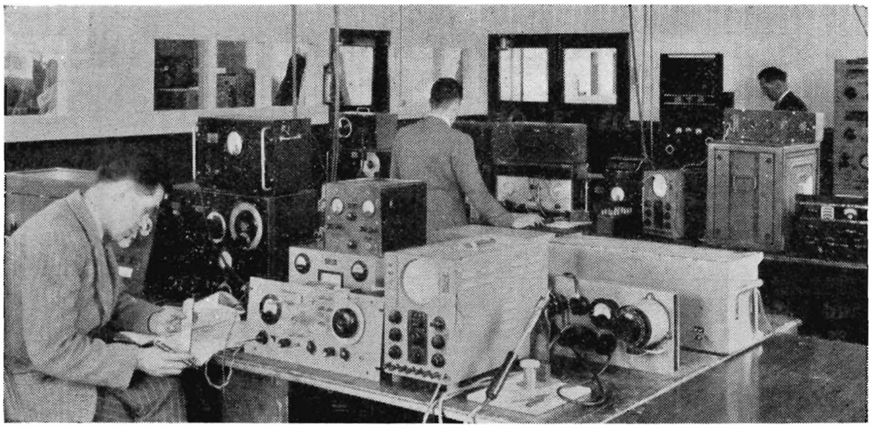
Scientists are recruited by the Supply Ministry in two ways. Permanent staff are engaged by the Civil Service Commission, which holds Selection Boards for prospective employees continuously throughout the year. Special posts for permanent staff, demanding unusual qualifications, are advertised widely by the Commission in the Press.

Unestablished staff are engaged by the Supply Ministry itself, which announces posts through the Press almost continually. Unestablished staff are always encouraged to apply to the Civil Service Commission for establishment—that is, employment on a pensionable basis.

Scientific posts within the Civil Service fall into two broad divisions—the class of Scientific Officer which is open to First or Second Class Honours graduates in science subjects who have the capacity for initiating research, and that of Experimental Officer open both to graduates (including those with "general" degrees) and people with other qualifications such as the Higher National Certificate.

These classes are sub-divided into the grades of Scientific Officer, Senior Scientific Officer and Principal Scientific Officer; and Assistant Experimental Officer, Experimental Officer and Senior Experimental Officer.

Above these ranks come Senior Principal Scientific



Part of a laboratory dealing with carrier equipment.

Officer, Principal Scientific Officer, Deputy Chief Scientific Officer and Chief Scientific Officer.

Promotion for both permanent and temporary staff in these grades is entirely by merit. In the regular reviews carried out by the Ministry, great care is taken to ensure that efficient scientists are promoted as soon as they attain the standard of the next higher grade.

Up to the rank of Principal Scientific Officer (which outstanding scientists should reach in the early thirties and others of proved efficiency a little later) promotion prospects are excellent. Beyond that grade posts are more limited, and promotion depends on the occurrence of vacancies or special needs.

Salaries for the Scientific Officer and Experimental Officer classes are on scales which differ for London and the Provinces, somewhat lower rates being paid to women.

The scales of pay, which rise by annual increments, for Scientific Officers working in London are as follows:—

S.O.	£400 - £650
S.S.O.	£750 - £950
P.S.O.	£1,000 - £1,375
S.P.S.O.	£1,500 - £1,750
D.C.S.O.	£1,850 - £2,125
C.S.O.	According to appointment.

The following are the scales for the equivalent grades working in the provinces:—

S.O.	£380 - £620
S.S.O.	£720 - £870
P.S.O.	£960 - £1,295
S.P.S.O.	£1,420 - £1,650
D.C.S.O.	£1,750 - £2,025
C.S.O.	According to appointment.

Ministry Establishments

A full list of Ministry Establishments describing the working going on in each, would obviously take far more space than is available here. The following list, however, gives details (necessarily brief) of the Establishments chiefly concerned with electronics:—

The Armament Design Establishment carries out for all three Services the development and design of armaments and ammunition up to the production stage. It works in close liaison with the

Armament Research Establishment where fundamental and applied research goes on into explosive phenomena, pyrotechnics, ballistics, metallurgy, radiology and other subjects. In addition to experimental work, much theoretical research is carried out at the Establishment which provides a valuable advisory service to industry. Allied to these Establishments is the

Explosives Research and Development Establishment which deals with chemical research and the protection of ammunition against climate. It carries out research for the Home Office on industrial explosives and the use of high-pressure acetylene.

The Radar Research and Development Establishment is responsible for all research, design and development work in connexion with radar for military purposes. In addition, it deals with radio and radar methods of making ballistics measurements.

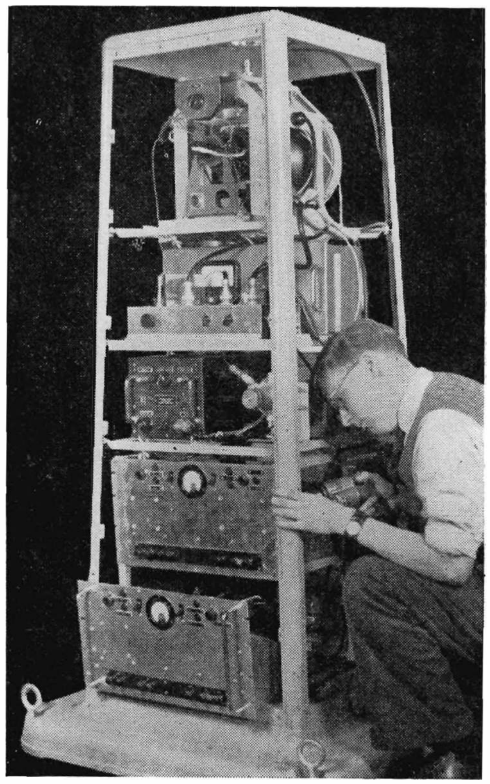
The Telecommunications Research Establishment is mainly concerned with the research and development of radar and radar navigational aids for the R.A.F. and for civil aviation. It also carries out basic radio and electronics research for the Department of Scientific and Industrial Research and provides a consultative service on electronics for industry.

The Signals Research and Development Establishment deals with communications by both radio and line. It is also responsible for the research and development on electronic equipment for various Services purposes and for television.

The Royal Aircraft Establishment is divided into many specialized departments. They carry out fundamental research on aerodynamics, aeronautical engineering, aircraft armament and equipment (including auto-pilots, navigational aids and electrical and communications systems) and of course, radio.

Apart from these Establishments, a great deal of work on the application of electronics goes on at the Ministry's Proof and Experimental Establishments, responsible for munitions trials which are situated in various parts of the country.

Constructing a recorder for automatically plotting the polar diagrams of directional aerials.



Harmonic Analysis of Waves up to Eleventh Harmonic

(Odd Harmonics only)

By Philip Kemp, M.Sc., M.I.E.E.

THE same grouping of selected ordinates is here adopted as in the analysis of waves up to and including the fifth harmonic, both odd and even,* but as in the present instance the even harmonics are assumed to be absent, only one-half of the wave is necessary, since both halves are now similar. For the purpose of this analysis any D.C. component must first be eliminated as before. The zero point may be arbitrarily chosen at any position, but again it is usually convenient to choose for this purpose the point where the resultant wave crosses the x-axis prior to rising in the positive direction.

There are twelve unknowns to be determined in this analysis, viz., the magnitudes and phase angles of the fundamental and the third, fifth, seventh, ninth and eleventh harmonics. It is therefore necessary to measure the values of twelve selected ordinates, these being chosen at 0°, 15°, 30° . . . 165° with respect to the arbitrary zero point. These ordinates are grouped in pairs, each pair consisting of ordinates equidistantly spaced on either side of the zero point.

As before, let one pair of these ordinates be represented by y_θ and $y_{-\theta}$. (Subscripts are used in two senses. The subscript $_3$ in Y_3 denotes that it is the third harmonic that is being considered, while the subscript $_{60}$ in y_{60} denotes that it is the ordinate at 60° from the arbitrary zero that is under consideration.)

* "*Harmonic Analysis*," by Philip Kemp, *Electronic Engineering, June, 1942.*

Then:

$$\begin{aligned} y_\theta - y_{-\theta} &= Y_1\sin(\theta+\alpha_1) + Y_3\sin(3\theta+\alpha_3) + \dots\dots\dots \\ &\quad - Y_1\sin(-\theta+\alpha_1) - Y_3\sin(-3\theta+\alpha_3) - \dots \\ &= 2Y_1\cos\alpha_1 \sin\theta + 2Y_3\cos\alpha_3 \sin3\theta + \dots\dots \\ &= 2A_1\sin\theta + 2A_3\sin 3\theta + \dots\dots \end{aligned}$$

where $A_1 = Y_1\cos\alpha_1$, $A_3 = Y_3\cos\alpha_3$, etc.

The coefficients Y_1, Y_3, etc., and α_1, α_3, etc., are constants depending upon the composition of the wave, while θ is equal to some known angle determined by the position of the selected ordinates.

Proceeding in the same way, but taking the sum instead of the difference of each pair of ordinates, we get:

$$\begin{aligned} y_\theta + y_{-\theta} &= Y_1\sin(\theta+\alpha_1) + Y_3\sin(3\theta+\alpha_3) + \dots\dots\dots \\ &\quad + Y_1\sin(-\theta+\alpha_1) + Y_3\sin(-3\theta+\alpha_3) + \dots \\ &= 2Y_1\sin\alpha_1 \cos\theta + 2Y_3\sin\alpha_3 \cos 3\theta + \dots\dots \\ &= 2B_1\cos\theta + 2B_3\cos 3\theta + \dots\dots \end{aligned}$$

where $B_1 = Y_1\sin\alpha_1$, $B_3 = Y_3\sin\alpha_3$, etc.

Twelve ordinates are measured at intervals of 15° commencing at $\theta = 0°$, and these are arranged in pairs as follows.

DIFFERENCES	SUMS
$y_0 - y_0 = 0$	$y_0 + y_0 = 2y_0$
$y_{15} - y_{-15} = y_{15} + y_{165}$	$y_{15} + y_{-15} = y_{15} - y_{165}$
$y_{30} - y_{-30} = y_{30} + y_{150}$	$y_{30} + y_{-30} = y_{30} - y_{150}$
$y_{45} - y_{-45} = y_{45} + y_{135}$	$y_{45} + y_{-45} = y_{45} - y_{135}$
$y_{60} - y_{-60} = y_{60} + y_{120}$	$y_{60} + y_{-60} = y_{60} - y_{120}$
$y_{75} - y_{-75} = y_{75} + y_{105}$	$y_{75} - y_{-75} = y_{75} - y_{105}$
$y_{90} - y_{-90} = 2y_{90}$	$y_{90} + y_{-90} = 0$

Expanding these equations we have :—

$$\begin{aligned} y_0 - y_0 &= 0 \\ y_{15} - y_{-15} &= 0.5176A_1 + 1.4142A_3 + 1.9318A_5 + 1.9318A_7 + 1.4142A_9 + 0.5176A_{11} \\ y_{30} - y_{-30} &= A_1 + 2A_3 + A_5 - A_7 - 2A_9 - A_{11} \\ y_{45} - y_{-45} &= 1.4142A_1 + 1.4142A_3 - 1.4142A_5 - 1.4142A_7 + 1.4142A_9 + 1.4142A_{11} \\ y_{60} - y_{-60} &= 1.7320A_1 - 1.7320A_5 + 1.7320A_7 - 1.7320A_{11} \\ y_{75} - y_{-75} &= 1.9318A_1 - 1.4142A_3 + 0.5176A_5 + 0.5176A_7 - 1.4142A_9 + 1.9318A_{11} \\ y_{90} - y_{-90} &= 2A_1 - 2A_3 + 2A_5 - 2A_7 + 2A_9 - 2A_{11} \end{aligned}$$

$$\begin{aligned} y_0 + y_0 &= 2B_1 + 2B_3 + 2B_5 + 2B_7 + 2B_9 + 2B_{11} \\ y_{15} + y_{-15} &= 1.9318B_1 + 1.4142B_3 + 0.5176B_5 - 0.5176B_7 - 1.4142B_9 - 1.9318B_{11} \\ y_{30} + y_{-30} &= 1.7320B_1 - 1.7320B_5 - 1.7320B_7 + 1.7320B_{11} \\ y_{45} + y_{-45} &= 1.4142B_1 - 1.4142B_3 - 1.4142B_5 + 1.4142B_7 + 1.4142B_9 - 1.4142B_{11} \\ y_{60} + y_{-60} &= B_1 - 2B_3 + B_5 + B_7 - 2B_9 + B_{11} \\ y_{75} + y_{-75} &= 0.5176B_1 - 1.4142B_3 + 1.9318B_5 - 1.9318B_7 + 1.4142B_9 - 0.5176B_{11} \\ y_{90} + y_{-90} &= 0 \end{aligned}$$

There are here twelve coefficients, viz., A_1, A_3, etc., B_1, B_3, etc. and sufficient equations to enable all six pairs to be evaluated in terms of $y_0, y_{15}, \dots\dots y_{165}$.

Solved in this way, we get

$$\begin{aligned} A_1 &= 0.0431y_{15} + 0.0833y_{30} + 0.1178y_{45} + 0.1444y_{60} + 0.1610y_{75} + 0.1667y_{90} + 0.1610y_{105} + 0.1444y_{120} + 0.1178y_{135} \\ &\quad + 0.0833y_{150} + 0.0431y_{165} \\ A_3 &= 0.1178y_{15} + 0.1667y_{30} + 0.1178y_{45} - 0.1178y_{75} - 0.1667y_{90} - 0.1178y_{105} + 0.1178y_{135} + 0.1667y_{150} + 0.1178y_{165} \\ A_5 &= 0.1610y_{15} + 0.0833y_{30} - 0.1178y_{45} - 0.1444y_{60} + 0.0431y_{75} + 0.1667y_{90} + 0.0431y_{105} - 0.1444y_{120} - 0.1178y_{135} \\ &\quad + 0.0833y_{150} + 0.1610y_{165} \\ A_7 &= 0.1610y_{15} - 0.0833y_{30} - 0.1178y_{45} + 0.1444y_{60} + 0.0431y_{75} - 0.1667y_{90} + 0.0431y_{105} + 0.1444y_{120} - 0.1178y_{135} \\ &\quad - 0.0833y_{150} + 0.1610y_{165} \\ A_9 &= 0.1178y_{15} - 0.1667y_{30} + 0.1178y_{45} - 0.1178y_{75} + 0.1667y_{90} - 0.1178y_{105} + 0.1178y_{135} - 0.1667y_{150} + 0.1178y_{165} \\ A_{11} &= 0.0431y_{15} - 0.0833y_{30} + 0.1178y_{45} - 0.1444y_{60} + 0.1610y_{75} - 0.1667y_{90} + 0.1610y_{105} - 0.1444y_{120} + 0.1178y_{135} \\ &\quad - 0.0833y_{150} + 0.0431y_{165}. \end{aligned}$$

$$B_1 = 0.1667y_0 + 0.1610y_{15} + 0.1444y_{30} + 0.1178y_{45} + 0.0833y_{60} + 0.0431y_{75} - 0.0431y_{105} - 0.0833y_{120} - 0.1178y_{135} - 0.1444y_{150} - 0.1610y_{165}$$

$$B_3 = 0.1667y_0 + 0.1178y_{15} - 0.1178y_{45} - 0.1667y_{60} - 0.1178y_{75} + 0.1178y_{105} + 0.1667y_{120} + 0.1178y_{135} - 0.1178y_{165}$$

$$B_5 = 0.1667y_0 + 0.0431y_{15} - 0.1444y_{30} - 0.1178y_{45} + 0.0833y_{60} + 0.1610y_{75} - 0.1610y_{105} - 0.0833y_{120} + 0.1178y_{135} + 0.1444y_{150} - 0.0431y_{165}$$

$$B_7 = 0.1667y_0 - 0.0431y_{15} - 0.1444y_{30} + 0.1178y_{45} + 0.0833y_{60} - 0.1610y_{75} + 0.1610y_{105} - 0.0833y_{120} - 0.1178y_{135} + 0.1444y_{150} + 0.0431y_{165}$$

$$B_9 = 0.1667y_0 - 0.1178y_{15} + 0.1178y_{45} - 0.1667y_{60} + 0.1178y_{75} - 0.1178y_{105} + 0.1667y_{120} - 0.1178y_{135} + 0.1178y_{165}$$

$$B_{11} = 0.1667y_0 - 0.1610y_{15} + 0.1444y_{30} - 0.1178y_{45} + 0.0833y_{60} - 0.0431y_{75} + 0.0431y_{105} - 0.0833y_{120} + 0.1178y_{135} - 0.1444y_{150} + 0.1610y_{165}$$

(In the above equations it should be noted that the ordinate itself may be either positive or negative.)

For the purpose of actual evaluation in the case of a particular analysis, the various coefficients may be conveniently arranged in the form of a schedule as shown in Tables "A" and "B".

Table of "A" values for analysis up to the eleventh harmonic (Odd harmonics only)

		A_1		A_3		A_5		A_7		A_9		A_{11}	
Angle	Ordinate	Multiplier	Product	Multiplier	Product	Multiplier	Product	Multiplier	Product	Multiplier	Product	Multiplier	Product
0°		—		—		—		—		—		—	
15°		0.0431		0.1178		0.1610		0.1610		0.1178		0.0431	
30°		0.0833		0.1667		0.0833		−0.0833		−0.1667		−0.0833	
45°		0.1178		0.1178		−0.1178		−0.1178		0.1178		0.1178	
60°		0.1444		—		−0.1444		0.1444		—		−0.1444	
75°		0.1610		−0.1178		0.0431		0.0431		−0.1178		0.1610	
90°		0.1667		−0.1667		0.1667		−0.1667		0.1667		−0.1667	
105°		0.1610		−0.1178		0.0431		0.0431		−0.1178		0.1610	
120°		0.1444		—		−0.1444		0.1444		—		−0.1444	
135°		0.1178		0.1178		−0.1178		−0.1178		0.1178		0.1178	
150°		0.0833		0.1667		0.0833		−0.0833		−0.1667		−0.0833	
165°		0.0431		0.1178		0.1610		0.1610		0.1178		0.0431	
Totals		$A_1=$		$A_3=$		$A_5=$		$A_7=$		$A_9=$		$A_{11}=$	

Table of "B" values for analysis up to the eleventh harmonic (Odd harmonics only)

		B_1		B_3		B_5		B_7		B_9		B_{11}	
Angle	Ordinate	Multiplier	Product	Multiplier	Product	Multiplier	Product	Multiplier	Product	Multiplier	Product	Multiplier	Product
0°		0.1667		0.1667		0.1667		0.1667		0.1667		0.1667	
15°		0.1610		0.1178		0.0431		−0.0431		−0.1178		−0.1610	
30°		0.1444		—		−0.1444		−0.1444		—		0.1444	
45°		0.1178		−0.1178		−0.1178		0.1178		0.1178		−0.1178	
60°		0.0833		−0.1667		0.0833		0.0833		−0.1667		0.0833	
75°		0.0431		−0.1178		0.1610		−0.1610		0.1178		−0.0431	
90°		—		—		—		—		—		—	
105°		−0.0431		0.1178		−0.1610		0.1610		−0.1178		0.0431	
120°		−0.0833		0.1667		−0.0833		−0.0833		0.1667		−0.0833	
135°		−0.1178		0.1178		0.1178		−0.1178		−0.1178		0.1178	
150°		−0.1444		—		0.1444		0.1444		—		−0.1444	
165°		−0.1610		−0.1178		−0.0431		0.0431		0.1178		0.1610	
Totals		$B_1=$		$B_3=$		$B_5=$		$B_7=$		$B_9=$		$B_{11}=$	

The actual analysis is carried out by entering in the second column the values of the ordinates at the appropriate phase angles. These ordinate values are multiplied by the various coefficients, the resulting products being entered in the blank columns and the totals being entered at the foot of each column. Care must be taken over the algebraic sign of these products, since either or both the ordinate and the multiplier may be positive or negative.

A great advantage possessed by this method of analysis is that the actual calculations, always tedious, can be carried out by a person ignorant of the principles involved, thus saving the time of a senior technical engineer. Nothing beyond a simple capacity to operate a slide rule is required, and even this is not essential. A quantitative knowledge of the composition of a wave is often desired, but in many cases the analysis is neglected on account of the valuable time of a skilled operator that is demanded. With this method all this is obviated, since the analysis can be carried out as a routine operation.

A further advantage lies in the fact that when a wave is symmetrical about the 90° and 270° ordinates, the labour of evaluation is halved, since all the *B* terms become zero.

To facilitate matters when a number of analyses are required, a template can be constructed by pasting the *A* and *B* schedules on to a sheet of strong card and cutting away the card in the regions occupied by the blank columns. The template can then be laid on a sheet of paper and the appropriate figures filled in. The same template can be used over and over again, while any set of calculations can immediately be made intelligible by replacing the template over them.

The amplitudes of the fundamental and the n^{th} harmonic are given by:

$$Y_1 = \sqrt{A_1^2 + B_1^2}$$

and

$$Y_n = \sqrt{A_n^2 + B_n^2}.$$

The corresponding phase angles are:

$$\alpha_1 = \tan^{-1} B_1/A_1$$

and

$$\alpha_n = \tan^{-1} B_n/A_n.$$

There are, however, four possible values of α_1, etc., one in each quadrant. To ascertain which quadrant is the correct one, it is necessary to take into account the sign, + or −, of the *A* and B terms. If *B* is positive, then α is in either the first or second quadrant. If *A* is positive, then α is in either first or fourth quadrant. Thus if *A* and *B* are both positive, the angle α is in the first quadrant. If *B* is positive and *A* is negative, the angle α is in the second quadrant, and should be taken as $(180° - \alpha^1)$ where α^1 is the angle in the first quadrant obtained by the evaluation of $\tan^{-1} B/A$, assuming both *B* and *A* to be positive. If both *B* and *A* are negative, then α is in the third quadrant and is equal to $(180° + \alpha^1)$, and finally if *B* is negative and *A* is positive, α is in the fourth quadrant and is equal to $(360° - \alpha^1)$.

The actual quadrant in which α is situated can easily be ascertained by reference to the following table.

Value of α

A is positive *B* is positive	α is in first quadrant $\alpha = \alpha^1$
A is negative *B* is positive	α is in second quadrant $\alpha = 180° - \alpha^1$
A is negative *B* is negative	α is in third quadrant $\alpha = 180° + \alpha^1$
A is positive *B* is negative	α is in fourth quadrant $\alpha = 360° - \alpha^1$

This method of harmonic analysis is mathematically accurate provided the wave under examination contains no harmonics higher than the eleventh. If higher harmonics are present, their effects are averaged out among the lower ones, and on this account small errors may be introduced. In practice, however, and especially if the higher harmonics are relatively small in amplitude, the error is generally small and is usually quite negligible so far as the fundamental and the first few harmonics are concerned. The error is certainly within the limits of experimental accuracy where measurements are taken from an oscillogram.

For the rapid but approximate analysis of a wave containing no even harmonics, the following schedules may be used. These schedules enable the fundamental, third and fifth harmonics to be approximately determined, although it must be understood that if higher harmonics are present in appreciable amount, the error in determining the fifth (and to a lesser degree the third) harmonic may be considerable.

Again, if the wave is symmetrical about the 90° and 270° ordinates, it is only necessary to complete the *A* schedule, since all the *B* terms are equal to zero.

A values for approximate analysis up to the fifth harmonic (Odd harmonics only)

Angle	Ordinate	A_1 Multiplier	A_1 Product	A_3 Multiplier	A_3 Product	A_5 Multiplier	A_5 Product
0°		—		—		—	
30°		0.167		0.333		0.167	
60°		0.288		—		−0.288	
90°		0.333		−0.333		0.333	
120°		0.288		—		−0.288	
150°		0.167		0.333		0.167	
Totals		$A_1 =$		$A_3 =$		$A_5 =$	

B values for approximate analysis up to the fifth harmonic (Odd harmonics only)

Angle	Ordinate	B_1 Multiplier	B_1 Product	B_3 Multiduct	B_3 Product	B_5 Multiplier	B_5 Product
0°		0.333		0.333		0.333	
30°		0.288		—		−0.288	
60°		0.167		−0.333		0.167	
90°		—		—		—	
120°		−0.167		0.333		−0.167	
150°		−0.288		—		0.288	
Totals		$B_1 =$		$B_3 =$		$B_5 =$	

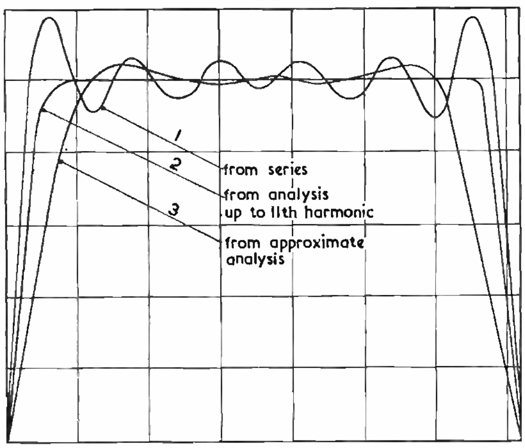
As an example an analysis is made of a rectangular wave of amplitude 100 units, both by the method going up to the eleventh harmonic, and also by the approximate method going up to the fifth harmonic only. This is an exceptionally severe test as this wave contains an infinity of harmonics only slowly decreasing in amplitude as the frequency is raised. The exact composition of a rectangular wave of 100 units amplitude is given by the series:

$$y = 4/\pi(100 \sin\theta + 100/3 \sin 3\theta + 100/5 \sin 5\theta + \ldots)$$

The analysis of this wave as worked out by the present method up to the eleventh harmonic, and also by the approximate method, is given in the table on the following page, together with the correct values as evaluated from the above series.

At first sight it appears as if the discrepancies are considerable, but when the three waves are plotted the remarkable fact emerges that the graphs of the waves obtained from the author's analyses are very much closer approximations to a pure rectangle than is the wave obtained from the first six terms of the true series. The three graphs are shown in Fig. 1 where this fact is immediately made apparent. The graph derived from the full analysis cannot

Harmonic	Amplitude per cent		
	from series	from analysis up to 11th harmonic	from approximate analysis
Fundamental	127.3	126.6	124.3
3rd	42.4	40.3	33.3
5th	25.5	21.7	9.1
7th	18.2	12.8	—
9th	14.1	6.9	—
11th	11.6	2.2	—



Approximations to Rectangular Wave
(1) by Series
(2) by Analysis up to 11th Harmonic
(3) by Approximate Analysis up to 5th Harmonic

Fig. 1. Comparison of waveforms.

be distinguished by eye from an actual rectangle from 15° to 165°, and that derived from the approximate analysis is a tolerable representation of a straight line from 30° to 150°, whereas the ripples in the curve derived from the series are quite appreciable. To emphasize the relative closeness of the three curves to the rectangular form, the values of the ordinates calculated by the three methods are given in the following table:

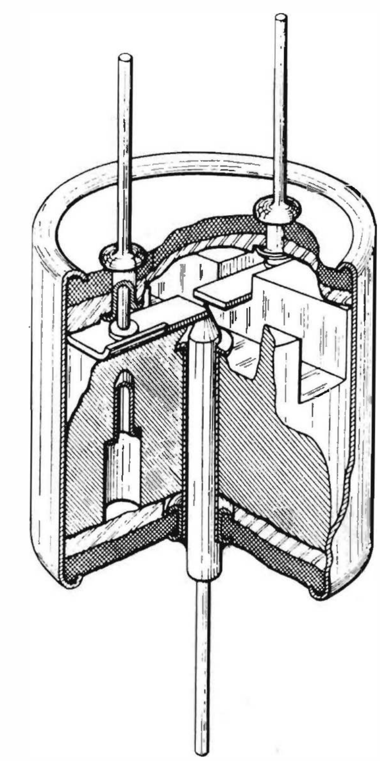
Angle	Value of ordinate		
	from series	from analysis up to 11th harmonic	from approximate analysis
0°	0	0	0
5°	62.7	44.7	22.9
10°	105.0	80.8	45.2
15°	118.1	100.02	64.5
30°	89.8	100.05	100.0
45°	107.3	100.05	105.1
60°	93.9	100.03	99.8
75°	105.4	99.95	98.8
90°	94.7	99.90	100.1

The Germanium Triode

THE first crystal triode, or transistor was demonstrated by the Bell Telephone Laboratories in 1948. Development on these crystal valves has been carried out in this country by the British Thomson-Houston Co., and by the General Electric Co. The latter company recently demonstrated a radio receiver using germanium crystal triodes.

The experimental receiver is of comparatively simple design and uses a two-circuit tuner to obtain reasonable selectivity and five G.E.C. germanium triodes in the R.F. amplifying, detector and push-bell A.F. output stages, which results in a receiver of sensitivity suitable for local station reception and an audio output of about 50 milliwatts.

The design of the germanium triode is illustrated below and is of a form which can be manufactured relatively easily. It consists of two phosphor-bronze blades 0.003in. thick and 0.04in. wide, supported in a moulded insulator. The gap between the blades is very critical and is obtained by mounting a single strip across a channel in the moulding and shearing a gap a few thousandths of an inch wide with a specially designed cutter. The germanium is soldered to the tip of a metal stub and is ground to a point, with an angle of 60°. Then by inserting the apex of the resulting cone into the gap between the blades, the essential two-point contact is made with the germanium and with a spacing which can be very accurately controlled. The three electrodes are then the two blades and the stub.



The operation of the triode depends on the fact that if a negative potential is applied to one of the blades (called the "collector") then the current to it can be varied by altering the positive voltage applied to the other blade (called the "emitter"). The "emitter" draws appreciable current when positive voltages are applied to it, in contrast to the thermionic valve in which the grid *voltage* is the important factor controlling the anode current. In the germanium triode the "emitter" *current* controls the "collector" current, i.e., it is a current-operated device rather than a voltage-operated.

The characteristics of the germanium triode result in a device of low input impedance (of the order of 500 ohms) and of relatively high output impedance (of the order of 30,000 ohms), and of course the associated circuits have to be designed with this in mind.

For an amplifier, a typical operating condition would be; collector: 1.5mA at − 30 volts, emitter: 0.5mA at + $\frac{1}{4}$ volt, and with proper impedance matching such an amplifier stage will give a power gain of 20-30db.

Recording Microwave Refractometer

By M. Lorant

An instrument which measures and records small differences in frequency betwen two resonant cavities has recently been developed by George Birnbaum at the U.S. National Bureau of Standards. In its present form, the new instrument can be adjusted over a wide band of microwave frequencies for measurement of dielectric constants of lossfree gases and changes in the dielectric constant of such gases and very low-loss liquids and solids. Its extremely high sensitivity permits operation with small test samples. The microwave refractometer should be readily adaptable to manufacture as a field model since the microwave components and electronic circuits are straightforward and compact. It has direct application in several fields of scientific research and industrial production, providing a convenient method for continuous monitoring of impurities in gases or liquids and for rapid testing of small solid samples. It could also be used as an ultra-micrometer and to measure the thermal expension of cavity materials.

The key operating principle of the refractometer is the comparison of two cavity resonators. A test sample (gas, liquid, or solid) is introduced into one of two otherwise identical cavities. The resultant difference in resonance frequency between the two cavities is then a measure of the dielectric constant of the test sample. Tests have shown that the sensitivity of the present instrument under laboratory conditions is 200 cycles per second at an operating frequency of 9,000 megacycles.

A klystron oscillator is used as a microwave signal source and is frequency-modulated with a sawtooth wave. The radio-frequency output from the klystron is fed to a T-junction which sends equal parts of the signal to the two cavity resonators, one functioning as a test cavity, the other as a frequency reference. The cavity outputs are then fed through identical crystal detectors, amplifiers, and pulse sharpeners. The pulse pairs, repeated at a rate determined by the sawtooth frequency, then go to a trigger circuit. The first pulse turns it on and the second turns it off. The output of the trigger circuit is a rectangular wave with constant amplitude, but variable width. The average value of this wave as measured in a meter circuit is then directly proportional to the frequency difference between the two cavities, provided that the " on-time " of the trigger circuit is also directly proportional to the frequency difference. The electronic circuits have been designed to give this linear relation between time and frequency.

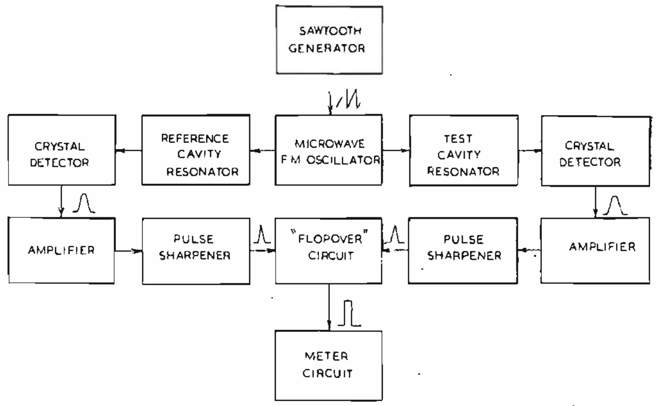
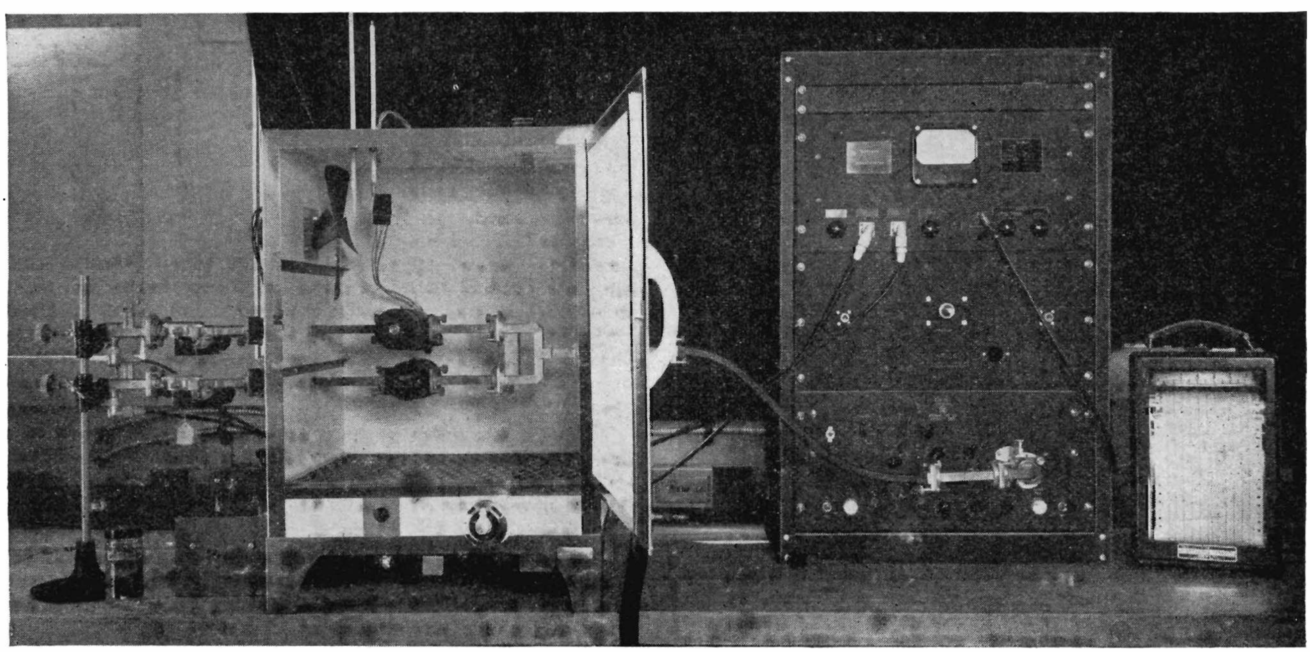


Fig. 1. Block schematic diagram

In calibrating the microwave refractometer, it is desirable to use rare gases such as argon or helium whose dielectric constants have been measured very precisely at optical frequencies. However, for greater convenience in actual operation the reference cavity has been equipped with a tuning plunger calibrated essentially in terms of the gas pressure in the test cavity.

The maximum sensitivity achievable by the refractometer is determined by its short-time stability, which depends essentially on background noise. Long-time stability depends chiefly on variations in temperature difference between the two cavities and the drift in centre frequency

Fig. 2. The recording microwave refractometer as used to measure the refractive index of an artificially controlled atmosphere



of the klystron with temperature. When long-time stability is needed, both of these effects can be controlled by proper temperature regulation.

With solids and liquids very high sensitivity to small changes in dielectric constant could be obtained by filling the entire test cavity with the material. But, except in the case of practically lossless substances, this would seriously decrease the Q of the cavity. On the other hand, if only a small fraction of the cavity volume is occupied by a low-loss substance (a small diameter cyclinder is convenient for this work) the Q would not be appreciably affected and sufficient sensitivity would be maintained. The position of the sample with respect to the electric field in the cavity will determine the sensitivity of the refractometer to changes in dielectric constant. Small liquid samples can be measured in the same way by placing the liquid in a quartz tube.

The restriction to low-loss materials is necessary because the present equipment is sensitive to changes in the Q of the test cavity. However, a direct extension of present techniques would avoid this limitation completely and permit simultaneous recording of changes in dielectric constant and loss.

In measuring the dielectric constants of gases, it is often convenient to use a flow technique in which a continuous stream of gas is drawn through the test cavity. This method has actually been in a preliminary experiment to record variations in the dielectric constant of an artificially controlled atmosphere.

A Two-Stage Cathode-Ray Tube

By M. D. Dudley, M.B.E., B.Sc. *

A NORMALLY accepted feature of a radio valve or cathode-ray tube is that the zero of current in the cathode circuit coincides with that in the anode circuit (i.e., the condition achieved when the cut-off or black-out volts are applied to the control electrode). A cathode-ray tube in which the gun continues to carry current after the black-out point has been reached may have certain advantages; the brightness/control-voltage characteristic need not have the long " tail " associated with normal tubes, and a portion of the input signal which lies beyond black-out (e.g., a sync pulse) may be allowed to impress voltage changes on one or other of the tube electrodes. Thus a tube of suitable design could be made to amplify the sync pulses while applying the picture signal only to modulation of the electron beam reaching the screen. Such a device could, of course, be constructed by including an amplifying valve in the electrode structure of a simple type of television cathode-ray tube, but a possibly simpler solution has presented itself in the form of two triode systems arranged in series along the same electron stream.

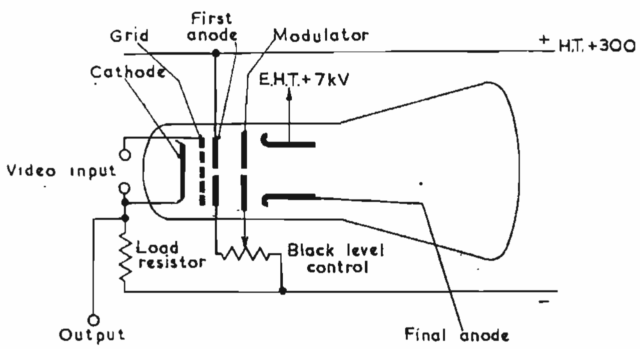


Fig. 1. General circuit arrangement of the two-stage C.R.T.

The two-stage C.R.T. has five elements, viz., indirectly heated cathode, grid, first anode, modulator and final anode. The general layout is shown in Fig. 1. The cathode is an indirectly heated flat disk similar to that used in the disk-seal types of valve employed in ultra short wave work, and is capable of emitting up to 40mA. A planar wire grid closely spaced in front of the cathode controls the flow of current to the first anode, which is a flat disk having a small hole in the centre. These first three electrodes thus constitute a triode valve in which voltage amplification of the grid signal occurs, the output being developed across the cathode load as shown. The remaining part of the electron gun consists of a normal triode-type of C.R.T. assembly with apertured modulating electrode and accelerator, except that the hole in the first anode becomes the cathode of the second section of the tube.

The mode of operation of the whole system may be described as follows.

Assuming that the conditions of the first triode portion are such as to permit electrons to emerge from the hole in the anode, i.e., the triode is passing current, these emergent electrons may be modulated in the usual way with reference to the cathode from which they were emitted, focussed and scanned over the screen. Thus the modulation signal is applied between the cathode and modulator electrodes, and this is achieved by the positioning of the load resistor in the cathode lead. The effect of altering the grid volts will be to alter the current available to the second section of the tube, but this effect is smaller than that due to the resultant amplified modulator signal. It may be seen that the picture signal must be applied to the grid in the sense that white drives the grid negatively. The sync pulses may be separated from the signal at the cathode and used in the usual way; they are positive-going and have been made to control a pair of time-bases without further amplification.

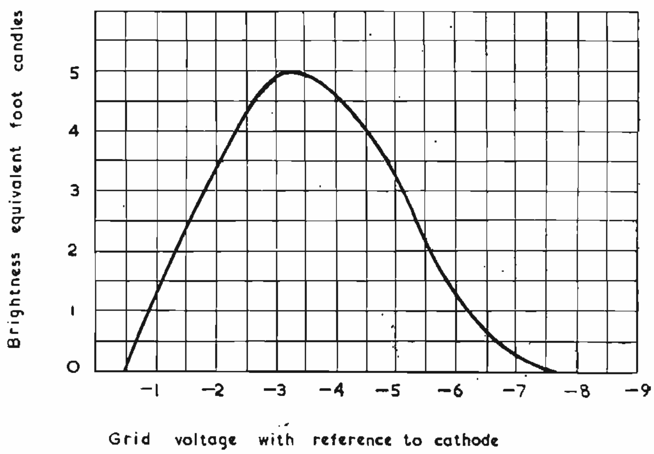


Fig. 2. Brightness/control grid characteristic

Over-driving of the grid negatively will limit or even cut off the current available to the second section; the effect of this will be to cause the beam current to return once more to zero. The complete grid-volts/brightness curve takes the form shown in Fig. 2, the abrupt commencement of the curve is due to the almost linear relationship between brightness and modulator voltage for a fixed cathode current. By employing separate inputs to grid and modulator, a family of brightness/modulator-volts curves may be obtained, each of which passes through a common black-out point but has a different slope.

* *Research Laboratories of The General Electric Company, Limited, Wembley.*

Transformer Iron Losses

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

FOR power transformers it is generally adequate to specify the total loss at the operating frequency and to consider the temperature rise which this loss is likely to produce, according to the type of design employed. In the design of audio frequency transformers, however, it becomes necessary to know more about the characteristics of the iron, in order to determine the response which the component will produce in association with the circuits to which it is connected. For this purpose a more complete analysis of the behaviour of the iron is often necessary, and the charts given in this data sheet enable such analysis to be made quite readily for two materials in common use.

Method of Analysis Used

The charts are based on an analysis of samples of ordinary grade transformer iron in laminations 0.016in. thick, and also a sample core of Mumetal in laminations 0.015in. thick. In the case of the Mumetal laminations, the size chosen had originally a cross section that varied round

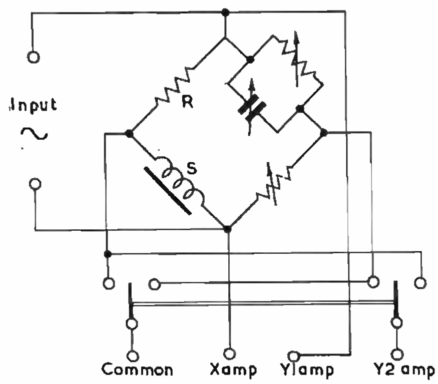


Fig. 1. Basic circuit of bridge used for analysis

the flux path of the magnetic circuit, due to the fact that the side limbs were not of exactly half the cross dimension of the centre limb. In order to ensure that the tests were made under conditions of uniform flux density throughout the magnetic circuit, these laminations were guillotined down to a new shape, such that the cross section of the magnetic path was uniform throughout its length, and the laminations were re-heat-treated to ensure that the Mumetal was operating under optimum conditions.

Coils were wound for each sample and the basic test circuit consisted of the bridge circuit shown in Fig. 1, where the coil S is that wound on the sample under test. The resistance R has a value small compared to the impedance of S at all measurement frequencies. Likewise, in order to obtain a balance, the impedance of the parallel combination of resistance and capacitance must be low compared to the single resistance value in the remaining arm of the bridge. The switching arrangement enables the output from the bridge to be changed so as to give various information about the losses in the core. Three special amplifiers were built to provide variable gain with zero phase shift in the range of measurement frequencies, to enable the output voltages from the bridge to give predetermined deflexion of a double beam oscilloscope. The readings obtained on the oscilloscope were calibrated by switching over the input to the three amplifiers to a separate calibrating circuit giving the same overall deflexion of the beams.

The resistance of the coils wound on the test samples and their self capacitance were measured, and allowance made for them, but in all the measurements taken their effect was less than the likely variation due to individual iron samples, so they were ignored.

Fig. 2 shows some of the patterns obtained on the oscilloscope and will also serve to interpret predictions

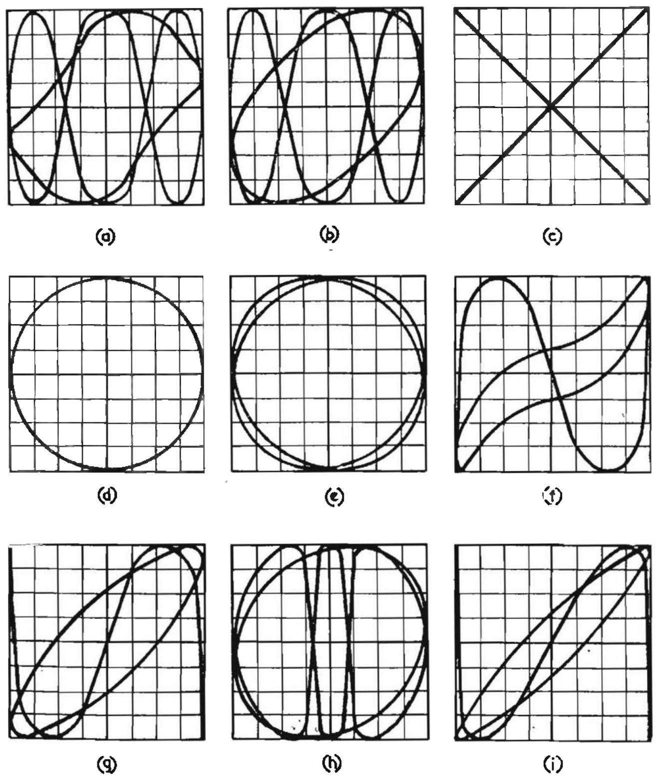


Fig. 2. Sample oscillograph patterns upon which analysis is based

given by the charts based upon this method of measurement. To take any individual measurement, the frequency of the input is adjusted to its required value, and the voltage of the calibrating section applied to the input of the X amplifier is adjusted to the voltage corresponding to the desired flux density for this measurement. The calibrating switch is then turned over to connect the oscilloscope amplifiers to the arrangement shown in Fig. 1, and the amplitude of input adjusted, with the switch at the bottom in the left hand position, until the amplitude of X deflexion is equal to that set up in the calibrating position, and which will have been adjusted to some specific amplitude on the screened transparency in front of the tube, by means of the gain control on the X amplifier.

Upon balance of the bridge, with the switch at the bottom of Fig. 1 in either position, the deflexion produced on the oscilloscope by the Y2 amplifier will give an indication of the waveform with the fundamental removed, against the fundamental as time base. The input applied to the Y1 amplifier in the left hand position of the switch is derived from the voltage across the resistance R, which represents the current waveform through the coil on the sample, while the input to the Y1 amplifier in the right hand position is derived from the resistance-capacitance combination having an identical component of fundamental potential across it without the harmonics due to the waveform of magnetizing current. The voltage input to the X amplifier is in each case that across one of the lower arms of the bridge, and as the upper arms are only of fractional impedance compared to the lower arms, the voltage waveform across the lower arms is sensibly identical with that of the input in both cases.

Having adjusted the balance of the bridge and the amplitude by the gain controls on the Y1 and Y2 amplifers so that throwing the switch shown at the bottom of Fig. 1 produces patterns that just lie between equal amplitude limits in both directions, as shown in Fig. 2, the calibrating switch is returned to the calibrating position, and the calibrating voltage applied to the input of the Y1 and Y2 amplifiers is adjusted until the trace again lies within the same maximum amplitude limits. Fig. 2(a) shows the type of pattern produced with the switch in Fig. 1 in the left hand position, that at (b) is produced with this switch in the right hand position, while that at (c) is the calibrating pattern. To interpret these results, the pattern of Fig. 2(b), together with the voltage calibration obtained for this pattern, enables the amplitude and phase of the fundamental component of the magnetizing current to be determined from the sloping ellipse. The relative amplitude of the calibrating voltages injected to the Y2 and Y1 amplifier will give the relation between the peak value of the waveform representing the harmonic components with the fundamental removed, to the peak value of the fundamental current waveform. This forms the basis for the interpretation of percentage harmonic used in Chart 2.

As a matter of interest, and to check the results obtained, a 90° phase shift was included in the input to the X amplifier only. This was produced by a resistance-capacitance network which was adjustable so as to give the correct phase shift at each frequency of measurement. To check for correct phase shift the pattern in the calibrating position, with the gain controls set correctly, is a perfect circle as shown at Fig. 2(d) in place of the X shown at (c). Failure to obtain exactly 90° phase angle will result in each pattern becoming slightly eliptical along opposite axes at 45°, producing a trace of the type shown at Fig. 2(e). The patterns produced upon correct adjustment of the bridge, corresponding to (a) and (b) without the 90° phase shift, are shown at (f) and (g) respectively. The phase readings obtained from the ellipse shown at (g) are complementary to those obtained from the ellipse shown at (h). A useful feature here is that one of the traces shown (f) is a hysteresis loop for this reading, with the difference that the H axis is vertical and the B axis horizontal.

These patterns are typical of those obtained with ordinary transformer iron, and are quite similar to those obtained with Mumetal at the lower flux densities, but at higher flux densities the pattern for Mumetal corresponding to that shown at (b) assumes a form of which (h) is typical, indicating that there are higher components in the harmonic waveform, due to the comparative suddenness with which Mumetal runs into saturation. A 90° phase shift modifies this to the form shown at (j).

The information obtained from a number of readings,

(i) at constant frequency and varying amplitude, and

(ii) at constant flux density and varying frequency, which means that the voltage across the sample must be kept proportional to frequency by appropriate adjustment of the input amplitude,

may be used to produce a complete analysis of the behaviour of the material under A.C. magnetization only. Utilizing the runs taken at constant flux density and variable frequency, for different amplitudes of flux density, characteristics may be plotted relating watts per cycle, or $I \cos \phi$, to frequency, and also reactive VA per cycle, or $I \sin \phi$. By this means the components of loss current due to hysteresis and eddy currents may be separated. The eddy current component, represented by the variable portion of the characteristic, is proportional to frequency when plotted in this way, and is also proportional to the square of the flux density at which measurement is made.

It was found that each metal appeared to have a characteristic phase angle for the component of magnetizing current due to eddy currents, as both the in-phase and quadrature components of magnetizing current can be divided into a fixed and variable component. Fig. 3 shows sample characteristics obtained at two different flux densities for standard transformer iron. The triangular shaped area above the dotted line represents the variable component due to eddy currents, while the rectangular area below the dotted line represents the fixed component due to hysteresis loss.

In practical audio frequency transformers, the flux density is of secondary interest, the primary factor being

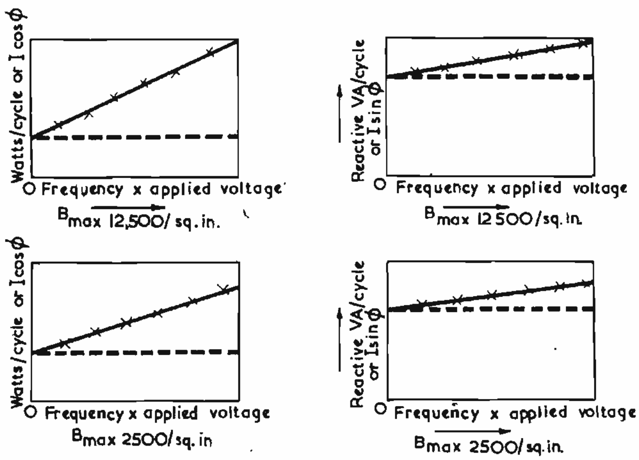


Fig. 3. Method of plotting results to separate losses

the applied input voltage, and in taking a frequency run the assumption will not be that of constant flux density but rather of constant input voltage. On this basis eddy current loss may be regarded as constant and having a fixed phase angle. Chart 4 applies the information derived from these tests to the determination of the fixed losses due to eddy currents in the core.

Having determined the component due to eddy currents which will be wholly at fundamental frequency, this component can be computed for each reading taken and subtracted vectorially from the total fundamental component of magnetizing current, so as to arrive at the component due to hysteresis and iron magnetization only. Having made this deduction, it is found that, for any given value of flux density, as frequency is varied the percentage harmonic becomes a constant fraction of the fundamental due to magnetizing current only. The phase and amplitude of the hysteresis component has been assumed constant for a given flux density by this method of deduction. This enables a series of curves to be plotted setting out the VA per cubic inch, in this case at a frequency of 50c/s, the phase angle of the hysteresis component of magnetizing current, and the percentage harmonic "generated" by this

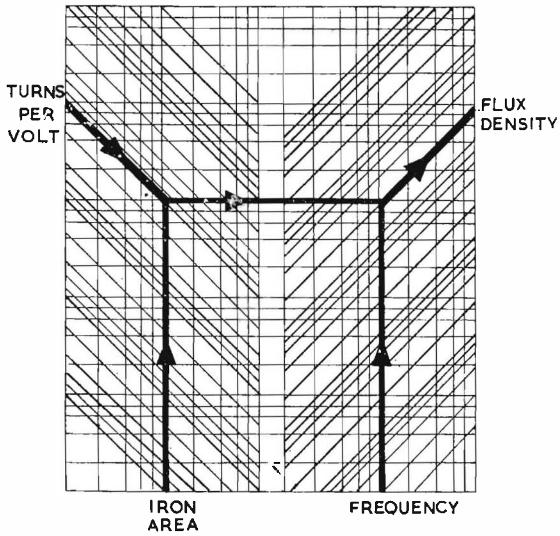


Fig. 4. Method of using Chart 1

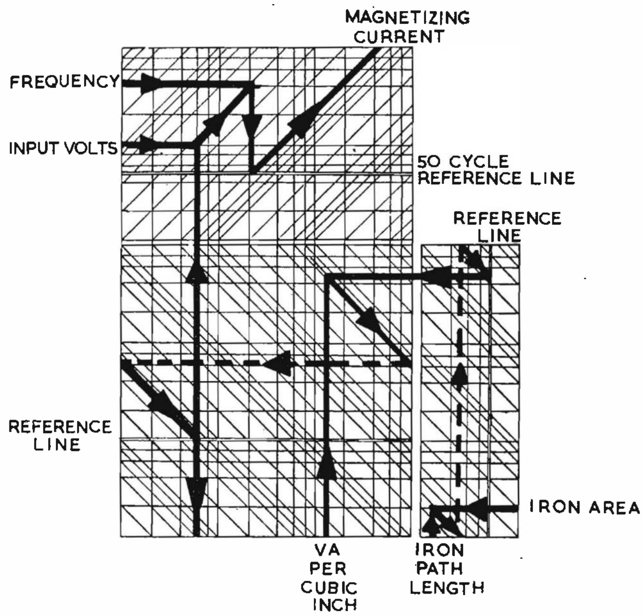


Fig. 6. Method of using Chart 3

component, against flux density, as produced in chart 2.

Application of Charts

Chart 1 provides a ready reference giving flux density in terms of iron cross section, turns per volt, and frequency. Chart 2 gives the *VA* per cubic inch referred to 50c/s, the phase angle of the hysteresis component of magnetizing current and the percentage harmonic referred to this component. At 50c/s the *VA* per cubic inch is given direct by this chart. For other frequencies the variation with frequency is taken into account by Chart 3. The definition of percentage harmonic as deduced for this chart was given earlier. While it does not conform strictly with the definition of total harmonic normally given, i.e., the root of the sum of the mean square values of the various components, it does perhaps give a figure that is more closely indicative of waveform. The harmonic content is referred as a percentage of the hysteresis component of magnetizing current only, so that with rising frequency, where the eddy current component becomes predominant, the harmonic expressed as a percentage of the total magnetizing current falls to a very low value. However, reference in this manner allows computation to be made with reasonable accuracy at all frequencies and flux densities.

Chart 3 enables the information given in Chart 2, relating to the operating conditions in the magnetic material, to be evaluated for any given core and frequency. The total *VA* at fundamental frequency is calculated and by reference to the voltage applied to the input winding the magnetizing current is deduced.

Chart 4 gives a direct calculation of the component of magnetizing current due to eddy current losses. As this may be regarded as a constant impedance referred to any winding, a reference is provided on this chart giving such impedance values referred to the number of turns in the winding.

The whole behaviour of the iron core at any given voltage amplitude may be computed by obtaining the magnetizing current at a series of frequencies with Charts 1, 2 and 3. This component at each frequency is added

Fig. 5. Method of using Chart 2

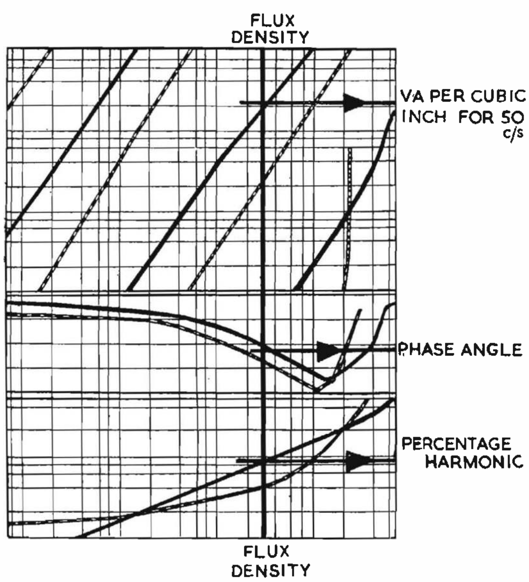
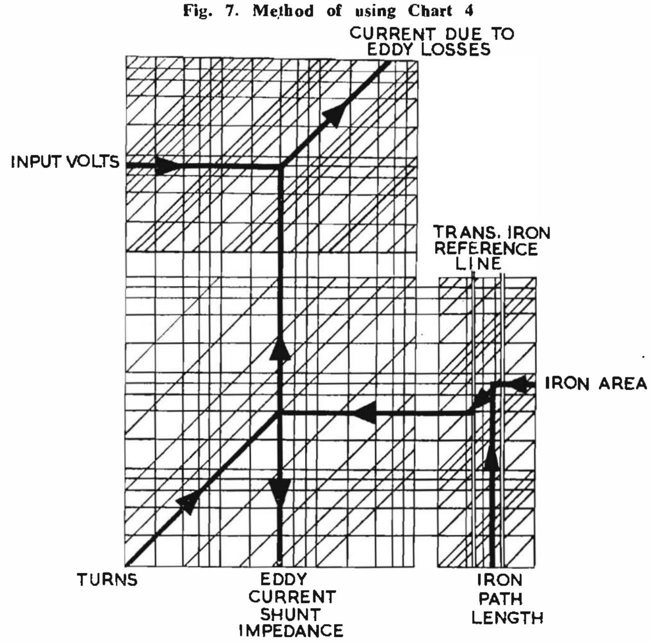


Fig. 7. Method of using Chart 4



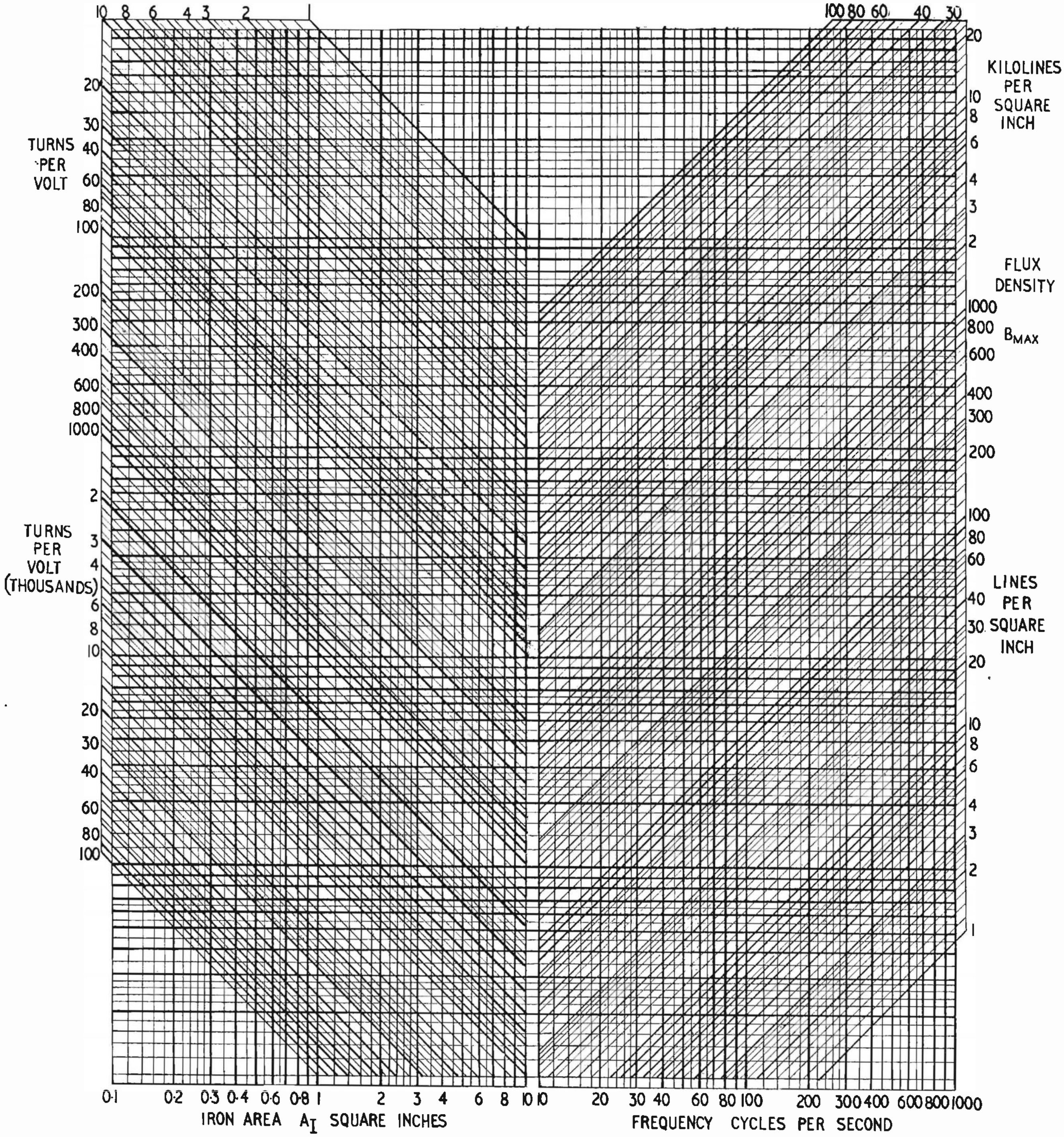


Chart 1. Flux density

vectorially to the component due to eddy current found by Chart 4 which will not vary with frequency, and the total magnetizing current will be given in magnitude and phase by this vector sum. The equivalent harmonic component can be calculated simply by dividing the percentage given by Chart 2 by the ratio between the total magnetizing current and the hysteresis component of it.

Chart 1

The use of the charts is illustrated by Figs. 4 to 7. Fig. 4 shows the use of Chart 1. Reference from the intersection between the appropriate turns per volt, and iron area in square inches scales, in the left hand portion of the chart, is made along the horizontal lines to intersect with the vertical frequency reference in the right hand portion, whence the flux density in lines per square inch is read at the right hand side.

Chart 2

This is simply a series of graphs. In the top portion *VA* per cubic inch for 50c/s values are obtained. The curves at the right, for the highest flux densities in each material, read off direct in *VA*. Successive curves of reference lines to the left of these use the same scale at the right (also repeated at the left) to indicate $VA \times 10^{-3}$, $VA \times 10^{-6}$ and $VA \times 10^{-9}$, according to the flux density used.

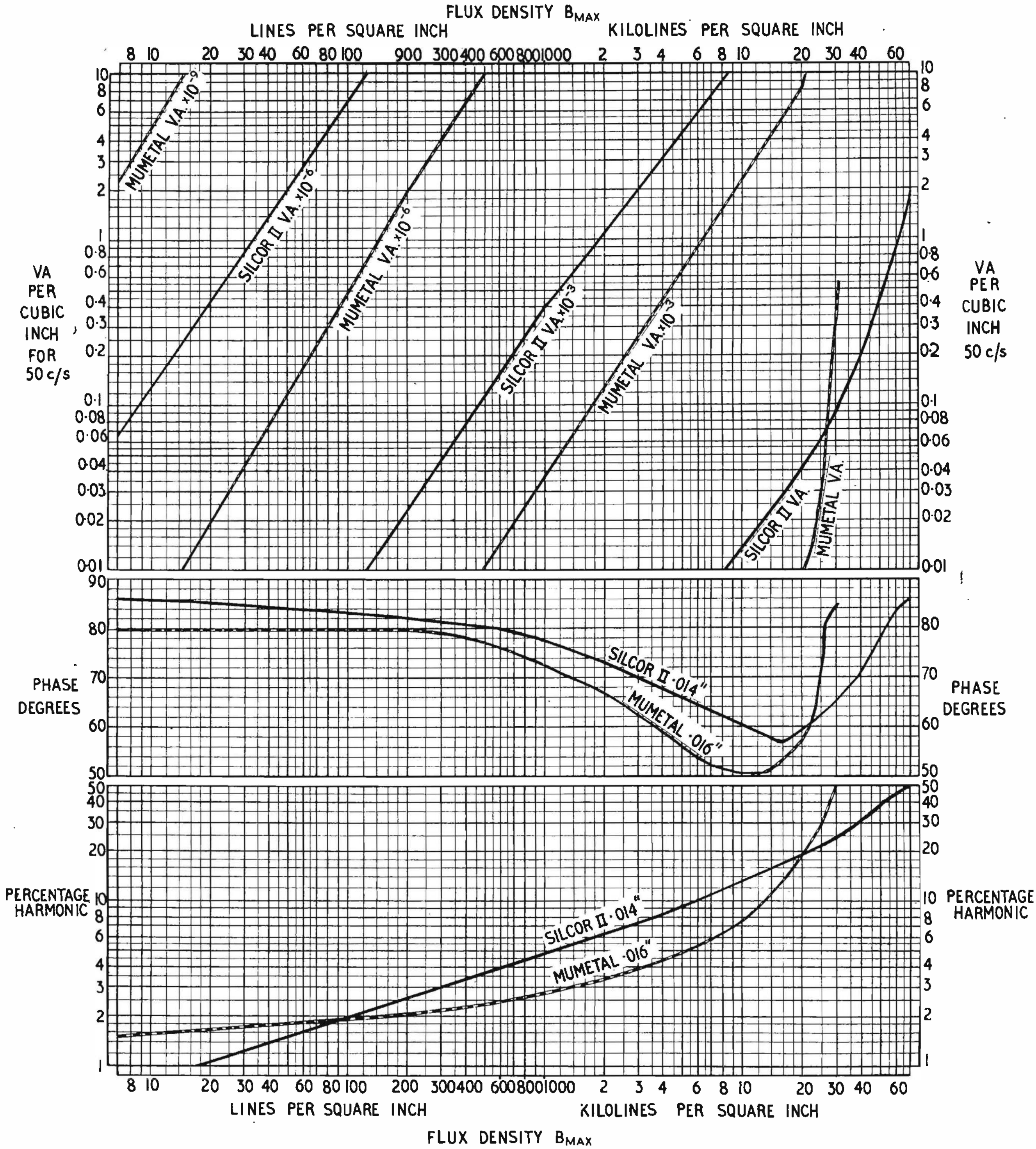


Chart 2. A.C. magnetization analysis

In the middle section of the chart, the phase of the component of magnetizing current due to hysteresis is given direct in degrees, while the bottom section gives the percentage harmonic expressing the peak amplitude of the waveform after removal of the fundamental component as a fraction of the fundamental component of current due to hysteresis loss.

Chart 3

This converts the value of *VA* per cubic inch for 50c/s given by Chart 2 into actual magnetizing current for the applied voltage required to produce the specified flux density at the given frequency in the iron core used. The iron cross section area is referred along the horizontal reference lines in the bottom right hand section of the chart to intersect with the iron path length along the vertical reference lines. Reference is made from the intersection point along the sloping reference lines in this section of the chart to the vertical reference line corresponding to 10 inches iron path length, indicated at the top as " Reference Line ". From this reference point the horizontal

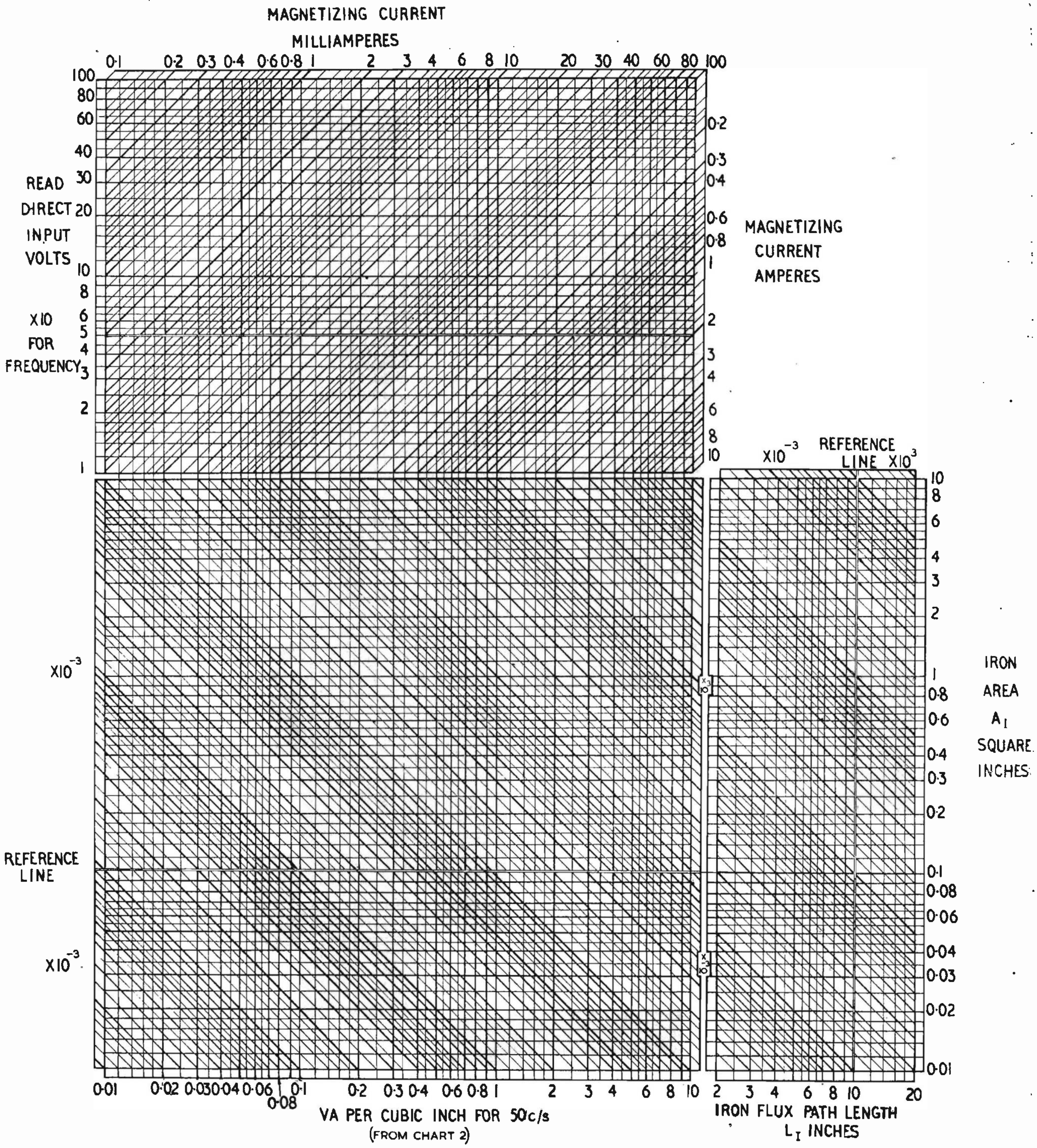


Chart 3. Magnetizing current due to hysteresis loss

reference is used into the bottom left hand portion of the chart. If the point of intersection between iron path length and cross section area does not fall on a slanting reference line that intersects directly with the 10 inch reference line, then reference is made as indicated by the dotted line in Fig. 6, and this indicates that the result obtained from the chart must be multiplied by 10^{-3}. If the reference shown by the dotted line had been in the reverse direction on the opposite side of the 10 inch reference line, then the result would have to be multiplied by 10^3.

From this horizontal reference in the left hand section of the chart intersection is made with the appropriate *VA* per cubic inch for 50c/s vertical reference lines, the value for which has been obtained from Chart 2. Reference is made from this point of intersection down the slanting lines in this section of the chart to the horizontal reference line one-third of the way from the bottom of this square section of chart. If, in order to intersect with this reference line, it is necessary to transfer to the opposite edge horizontally, as indicated by the further dotted line in Fig. 6, then the result obtained at the end of the operation

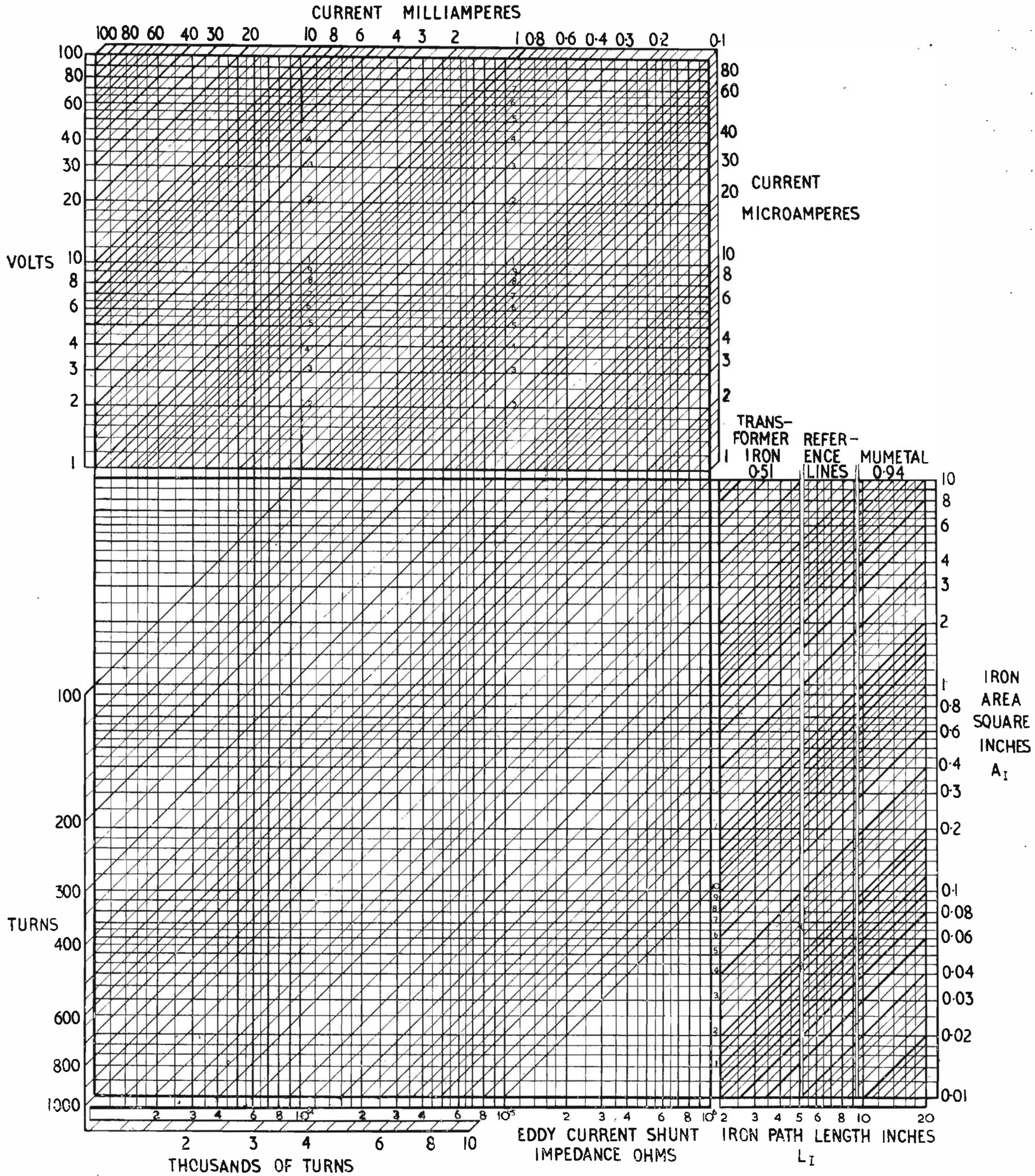


Chart 4. Magnetizing current due to eddy current losses

must be multiplied by 10^3 or 10^{-3} as indicated at the edge of the chart where the transfer is made.

Reference is made from the point of intersection on this horizontal reference line up the vertical reference lines to intersect with the horizontal volts reference in the top section of the chart. From this point of intersection reference is made along the sloping reference lines to intersect with a horizontal frequency reference line, the scale for which is ten times that used for voltage reference using the same lines. From this point of intersection reference is again made along the vertical lines to intersect with the 50c/s reference line, at the intersection with which, reference along the sloping lines gives the resulting magnetizing current. Fig. 6 will make this quite clear. In the particular example shown in Fig. 6, the transfer indicated by the two dotted lines results in multiplication of the final result first by 10^{-3}, then by 10^{3}, so that the direct reading indicated is correct in this case.

Chart 4

Fig. 7 illustrates the use of Chart 4. Intersection between the horizontal iron area reference lines and the vertical length of iron path lines is referred along the sloping lines to the appropriate reference line for the core material used. From this point of intersection reference is made along the horizontal lines to intersect with the sloping turns reference corresponding to the number of turns in the winding to which the loss is to be referred. Reference from this point of intersection down the vertical reference lines will give the eddy current shunt impedance referred to this winding, while reference up the same vertical lines to intersect with a horizontal volts reference will give the magnitude of magnetizing current due to eddy currents in this winding for any given applied voltage.

For standard transformer iron laminations 0.016in. thick, the phase angle of this current is 14° lagging on applied voltage, while for 0.015in. Mumetal the angle of lag is 22°.

Example 1.

A 1in. stack of wastefree type laminations, No. 29, has an iron area of 1 square inch and a flux path length of 6in. Assuming that 10 volts are applied to a winding of 250 turns, the values of B given in the table below are obtained for the frequencies shown from Chart 1. Applying this information to Chart 2, the lines marked $VA/\text{in.}^3/50\text{c/s}$, ϕ_h, and percentage h are obtained. Application of the VA per in.³ for 50c/s to Chart 3 produces the values of I_h shown. Values of $I_h \cos\phi_h$ and $I_h \sin\phi_h$ can readily be obtained by a slide rule giving trigonometrical functions. Use of Chart 4 shows that 10 volts applied to the 250 turn winding, giving an eddy current shunt impedance of 5,300 ohms,, produces a magnetizing current due to eddy currents of 1.9mA. For ordinary transformer iron the phase angle is 14°, so $I_e \cos\phi_e$ is 1.85mA and $I_e \sin\phi_e$ is 0.46mA. Adding these components to $I_h \cos\phi_h$ and $I_h \sin\phi_h$ gives the values of $I_t \cos\phi_t$ and $I_t \sin\phi_t$, from which I_t and ϕ_t the total magnetizing current at fundamental frequency and its phase to applied voltage are obtained. Dividing percentage h by I_t/I_h gives percentage t the percentage harmonic current, expressed as a percentage of the total magnetizing current.

	20c/s	50c/s	100c/s	200c/s	500c/s
B	45,000	18,000	9,000	4,500	1,800
$VA/\text{in}^3/50\text{c/s}$	0.3	0.035	0.012	0.004	0.001
ϕ_h	74°	58°	61°	66°	74°
Percentage h	36	18.5	12	9	6
I_h mA.	72	20	13	10	6
$I_h \cos\phi_h$	19.8	10.6	6.3	4.06	1.65
$I_h \sin\phi_h$	69.2	17	11.4	9.12	5.77
$I_t \cos\phi_t$	21.65	12.45	8.15	5.91	3.5
$I_t \sin\phi_t$	69.66	17.46	11.86	9.58	6.23
I_t mA.	73	21.5	14.4	11.3	7.15
ϕ_t	72.75°	54.5°	55.5°	58.33°	60.7°
Percentage t	35.5	17.2	10.85	8	5

It will be appreciated that the percentages given for harmonic are still expressing the peak value of harmonic current as a fraction of the peak value of the total magnetizing current at fundamental frequency. This does not include current due to energy transfer for which the transformer is primarily intended, and is essentially a higher figure than the harmonic voltage that will be introduced into the associated circuit, by a ratio approximating to that of the total primary current to the total magnetizing current component of it.

Example 2. Core of Non-Uniform Section Area.

For these cases two methods could be employed: each section of differing area could be treated separately on the basis shown in the previous example, and the total effect obtained by adding vectorially the final results for each section; or an adequate approximation can be made by using a rough equivalent size of uniform section. For the calculation of hysteresis component an average flux density, based on the volume distribution in the various areas, may be taken, and the horizontal reference on Chart 3 will be the total iron volume of the core. For the calculation of eddy current component, it is the ratio of area to path length that determines the shunt eddy current impedance, so an equivalent overall ratio should be obtained for use with Chart 4.

As an example a ⅝in. stack of No. 25 laminations can be divided into two sections: centre limb 1⅞in. long, 0.39sq.in. cross section; side limbs (in parallel as part of magnetic circuit) 4⅛in. long, 0.47sq.in. cross section. Multiplying out the total volume is found:

Centre limb: 0.73sq.in.
Side limbs: 1.94sq.in.

Total: 2.67sq.in.

The area giving equivalent average flux for hysteresis calculations will be

$$\frac{0.73 \cdot 0.39 + 1.94 \cdot 0.47}{2.67} = 0.45\text{sq.in.}$$

Equivalent path length to give the same volume is then $\frac{2.67}{0.45} = 5.9\text{in.}$ Thus on Charts 1 to 3 the dimensions to use are $A_i = 0.45$, $L_i = 5.9$.

Using the same reference cross section, i.e., 0.45sq.in. for Chart 4 dealing with eddy currents, the equivalent components of length giving the same reluctance are:

$$\text{Centre limb: } 1\tfrac{7}{8}\text{in.} \times \frac{0.45}{0.39} = 2.16\text{in.}$$

$$\text{Side limbs: } 4\tfrac{1}{8}\text{in.} \times \frac{0.45}{0.47} = 3.95\text{in.}$$

Total equivalent length: 6.11in.

Thus for Chart 4 one combination that may be used here is $A_i = 0.45$, $L_i = 6.11$. Any combination giving the same *ratio* would give the same result, but the area was chosen the same as that used for hysteresis calculations to demonstrate the slight difference in effective shape for computing the two forms of loss.

A Synchrophase Sound Installation*

This equipment is designed to overcome the echo effect experienced in large halls. This effect is eliminated by delaying the sound radiated by the loudspeakers until the natural sound has reached the audience so that sound from both sources is heard simultaneously.

The Synchrophase Sound unit which effects the necessary delay incorporates a high speed turntable, the edge of which is continuously coated with magnetic iron oxide. Four magnetic heads are situated so that the magnetizable edge of the turntable passes by each in turn. The first head records the sound on the magnetic coating, the recorded portion of which then passes by the two replay heads, spaced from the recording head to give the necessary delays. The spacing between the recording and replay heads is adjustable to give different delay times. After passing the two relay heads the recorded edge of the turntable then passes the erase head.

**Communication from E.M.I. Sales & Service Ltd.*

Letters to the Editor

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

Are We Becoming Slaves of Standardization?

Dear Sir,—In the past few years strenuous efforts have been made by various authoritative organizations, including learned Societies, Institutes and Institutions to introduce standardization into almost every form of human interest and activity. The onslaught on non-uniformity has perhaps been greatest where most needed, that is, on the printed word. But so many standards, technical terms, symbols and abbreviations have been produced that their application is more and more becoming a specialized business. There can be no doubt whatever that each of these serves a useful purpose within its own field; the purport of this letter is to explore the possibility of applying the general principles without being bound hand and foot to points of detail.

We must, of course, confine our attention to standards appertaining to electronic engineering, and particular emphasis is placed on those devised for telecommunication. To begin with, we cannot do better than consider the standard abbreviations for direct and alternating currents. We seem to be committed for ever to the abbreviations A.C. and D.C. whether we are referring to currents or to voltages; we must accept the rule that an alternating voltage of 200 should be expressed as 200V A.C., but the question which often arises is whether we should write a.c. or A.C.

Amendment No. 1: September, 1945, to BS.560: 1934[1], states that we may use a.c. when the abbreviation denotes an adjective. Presumably therefore we write "an a.c. voltage of 200" but "200V A.C." I suggest that this juggling with capitals and smalls is illogical, unnecessary, and aesthetically offensive when the abbreviation appears in both forms on a given page.

A number of abbreviations in capitals upset the balance of a printed page, and utilize valuable space; surely the obvious answer is to use lower case without qualification. We are then left with two problems: first, a sentence beginning with the abbreviation involves the use of capital and small letters, thus "A.c. voltages are developed . . ."; second, should we pander to the purist and hyphenate the abbreviation in its adjectival form? The writer approves the recommendation implied on page 2 of the amendment quoted, which omits the hyphen; its inclusion adds an unnecessary burden to the author, editor, printer and proof-reader; it contributes nothing to intelligibility.

The force of this argument will be appreciated if a few additional abbreviations of similar character are quoted: H.T., L.T., R.F., G.B., F.M. Truly their name is legion; how much simpler it would be if the lower case were made standard for all, and hyphens, drat them, eliminated. In making this suggestion, the author is aware that exceptions may be necessary, e.g., in sinusoidal quantities, where capital and lower case abbreviations represent different values. Even here, however, there is a simple method of avoiding possible doubts as to these values; if instead of using circumflexes and other devices, the values are printed in subscript, no confusion arises, whether the symbols are printed in capitals or lower case; thus, $V_{r.m.s.}$, V_{max}, V_{inst}, I_{pk}, I_{av} are self-explanatory. Care, however, has to be exercised if, for example, velocities and voltages are referred to in a monograph. British Standard 560 gives the symbol for velocity as v or V; obviously if V is used for voltages, v must be used for velocities, subscripts again being preferred to denote values.

Perhaps the most exacting and irritating series of standards is that appertaining to electronic valves; it is to be hoped that the existing British Standard No. B.S. 1409: 1947[2] represents finality for many years to come. No author, or for that matter, no student, of articles or books on electronic subjects should be without this standard; much as we may dislike it, its application is essential if chaos in the use of valve symbols is to be avoided.

Standards for abbreviating frequency terms are in a different category; here, there is need for rigid adherence to those recommended on page 3 of B.S. 204: 1943[3], viz., c/s, kc/s, Mc/s. These, however, are often flagrantly distorted and appear as c.p.s., p.p.s., k/s. K/CS. Kc, KC, M/cs, etc.; as a result articles by different authors appearing in one periodical frequently make use of different abbreviations for the same terms. There are only three symbols to worry about, c/s, kc/s, Mc/s; a plague take all the rest.

Another standard of vital interest to readers of this journal is the abbreviation for decibel. The recommended form is db, without a stop and without an appendage "s" if there are more than one. Let us see in how many ways we can flout this standard, DB, DB., Db, Db., db.; double this by adding S for the plural and we have ten different forms (all of which are non-standard). Here surely is a solid argument for uniformity. There is only one symbol, db, for decibels.

Now let's have a chat about full stops. B.S. 560: 1934 Amendment No. 1 says leave them out after single-word abbreviations *relating to units and quantities*, except where doubt may exist as to whether the letters represent a complete word or an abbreviation; put them in when the abbreviation represents more than one word. These are simple rules to apply, e.g., *ft in.*, *r.p.m.* (Note the lower case for *r.p.m.*; this also applies to *r.m.s.*).

Enough has now been said on abbreviations. The British Standard quoted is a sure and certain guide, provided that you have Amendment No. 1.

I hesitate to comment on standard forms of spelling, but the Concise Oxford Dictionary[4] supplies most of the answers if you read the preface carefully. The main points are the discarding of double consonants such as ll, ss. tt, leaving us with *paralleled, biased* and *pivoted;* freedom of choice with the suffix *ize* or *ise* according to house rules; dropping the mute *e* before suffixes when it serves no purpose, e.g., *desirable*, but *serviceable*, *milage* but *manageable*.

With regard to hyphens, beyond recommending their use for compound adjectives like *low-frequency* (distortion), *high-tension* (cable) the writer does not pretend to know better than the arrangers of the dictionary quoted. Read what they have to say in the preface.

Are we becoming slaves of standardization? Possibly, but even this is better than remaining masters of chaos and confusion.

Yours faithfully,

J. W. Godfrey.

REFERENCES

[1] British Standard 560:1934, "Engineering Symbols and Abbreviations." British Standards Institution. Amendment No. 1: September, 1945.

[2] British Standard 1409:1947, "Letter Symbols for Electronic Values." British Standards Institution.

[3] British Standard 204:1943, "Glossary of Terms used in Telecommunication."

[4] The Concise Oxford Dictionary, Oxford University Press.

Fatal Shock from a Television Receiver

Dear Sir,—I noted your commentary in the June issue, and agreed with the opinion that undue prominence had been given by the daily Press to a particularly unfortunate incident. I also noted in the July issue a correspondent, Mr. Voyce, perhaps quite naturally, even if a shade indignantly, proceeded in a denunciatory fashion to point out all the horrors of a domestic receiver.

A sense of proportion must be retained —otherwise many of the benefits and amenities that all of us have acquired for our homes would never have been available.

It is due only to careful design on the part of most manufacturers that the incidence of such risks is reduced to those very occasional and exceptional cases which could easily be due to the lack of precautions during the initial installation.

Past practice and experience coupled with present day manufacturing techniques can produce articles which have a risk incidence of considerably less than 0.001 per cent when operated under approved conditions. Factors related to safety requirements are, quite naturally, adapted to suit economical production; for how else could a product have a commercial future? The increase in the number of live-chassis receivers is the manufacturer's answer to the rising cost of materials; the present day table-model television receiver is an excellent example of the live-chassis technique. The public therefore can feel assured that designer and manufacturer are intensely concerned with producing an economically priced article which is as safe as any other domestic appliance in regular use.

Mr. Voyce focuses attention on the question of two-pin plugs, multiple adaptors, bayonet plugs and sockets, positive earthed D.C. supplies, transportable receivers and so on. "All of which" the dealers will add "make it impractical to ensure connexion so that the chassis is not live." I would like to add "even if there were non-reversible plugs on the back of the receiver."

True this may be—but no one will deny that there is a certain amount of moral responsibility on both sides. Radio manufacturers will undoubtedly continue to contribute improvements and safeguards in this direction, but is it not the dealers' responsibility to observe some of those precautions which are outside the manufacturers' control?

Some of Mr. Voyce's itemized comments can only relate to aged second-rate types of receivers, as there is in existence a B.S.I. specification which covers all the points he criticizes. This specification has been the subject of discussion and revision between B.S.I. and B.R.E.M.A.; the revised specification has been framed to ensure an even higher standard of engineering practice which is directly related to a policy of reducing every conceivable risk to a minimum.

My final comment in defence of British radio manufacturers is that electric fires, electric domestic irons, gas-operated jets and ovens are more likely sources of domestic hazards than a radio or television receiver. Accidents can happen with any of them, and risks with domestic equipment represents a hazard consistent with our present way of life.

Yours faithfully,

G. T. CLACK.

Piezo-Electric Crystal Devices

Dear Sir,—Mr. Kelly is to be congratulated on the vast amount of material and wealth of experimental detail which he has been able to compile in his article. It is to be expected that, in a work of this nature, minor errors will occur.

In particular, in part 2 of his article, Mr. Kelly explains the behaviour of a "bender bimorph" of rochelle salt. An element constructed in the way described would, I am compelled to say, fail completely to act as a transducer. If, however, the words "oppositely oriented" in the third line be replaced by "similarly oriented," then the explanation will be valid.

Later a reference is made to the concept of "the equivalent electromechanical circuit." I, personally, think this phrase is a little misleading and prefer to speak of the "equivalent electrical circuit" (of a mechanical system). In this connexion, it must not be forgotten that there are other methods of deriving equivalent electrical circuits, differing from the method Mr. Kelly has described, e.g., if one may be represented, not by a voltage, but by a current, a procedure often adopted in the study of loudspeakers, since the force, in this case, is a function of current more than of voltage. In this instance, an entirely different table of corresponding units will be required.

There is one more point in the article which I feel bound to contest, and that is the statement that the circuit shown in Fig. 11 is a single resonant circuit. I would be very interested to hear how this conclusion was arrived at, since applying Foster's Reactance Theorem to the non-redundant components in the primary circuit, there appear to be three resonances.

Yours faithfully,

PETER KELLETT, B.Sc.

The author replies:

Dear Sir.—My term "oppositely oriented" is taken to imply that the application of an electrical stress to the two plates will result in the expansion of one plate along a given axis, and a simultaneous contraction of the other plate. This was shown in the diagrams. In the practical case, the actual orientation of the plates will be governed by whether a series or parallel electrical connexion is to be made.

With reference to the second point, it is purely a matter of personal conviction. Mr. Kellett prefers one description, I prefer another. While I fully agree that there are other methods of deriving equivalent electrical circuits, the particular one described in my article is the one usually used on electrostatic devices; the one described by Mr. Kellett, the one usually used on electro mechanical. As I stated before, it is purely a matter of personal preference, either can be used, but in the one described by myself, it so happens that the mathematics work out a little simpler.

With regard to the third point, in the circuit of Fig. 11, the transformer representing the transducer is assumed ideal, i.e., with infinite primary impedance, etc., and would therefore have no effect on any resonances in the system. The diaphragm is rigidly connected to the crystal, so there will be no relative motion between the diaphragm and the crystal. The case, of course, is assumed to be rigid, and the diaphragm will move as a piston. Under these circumstances, only a single mechanical resonant circuit will ensue. As stated earlier in the article these are approximate equivalencies and certain simplifying assumptions are always made, i.e., that the diaphragm behaves as a piston, the crystal has only one resonant frequency, etc. If these assumptions are taken to the limit, they are obviously incorrect, but if applied over the limited frequency range (below the first resonant frequency of the structure) at which these microphones are used, the assumptions are valid.

Yours faithfully,

S. KELLY,

A Simple Frequency Comparison Circuit

Dear Sir.—I was very interested to read the letter by M. G. Beauchamp (May issue) describing his frequency comparison circuit. I have been using a "Magic Eye" as a beat indicator and can confirm that for such a simple and inexpensive circuit the results are very good, e.g., a frequency difference of 0.05c/s is easily distinguished, a figure which compares favourably with the 0.025c/s accuracy given for a more elaborate C.R.T. method (W. S. Wood, "Engineering," Vol. 171, p. 216).

The circuit shown below was designed for adjusting to equality frequencies from 25c/s upwards and differs from that of Mr. Beauchamp in that the input signals are mixed externally in the common cathode load of V1 and V2, and the resultant beat signal is fed to the indicator via a low pass filter. One advantage of this method is that for any input frequency, only the low beat frequency is fed to the indicator so that the indicator may be located some distance from the instrument with little alteration of performance.

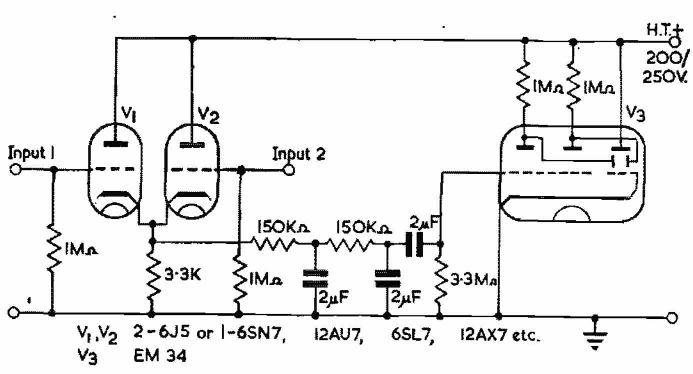
The circuit shown below is suitable for input signals greater than 2V, but where greater sensitivity is required V1 and V2 may be reconnected as amplifiers with common anode load. With this arrangement, however, a stabilized H.T. supply is usually necessary since slow variations in H.T. voltage are passed with little attenuation to the indicator and give rise to spurious deflexions. An alternative method, for which a stabilized supply is not required, is to amplify the signals and couple to V1 and V2 via high-pass filters, e.g., a $0.005\mu F$ coupling capacitor and a 1 megohm grid leak would be suitable for a single stage pre-amplifier.

If, in addition to adjusting frequencies to equality, it is required to compare different frequencies (i.e., n is not equal to unity) it would be an advantage to add a distorting circuit such as that described by Mr. Beauchamp.

Yours faithfully,

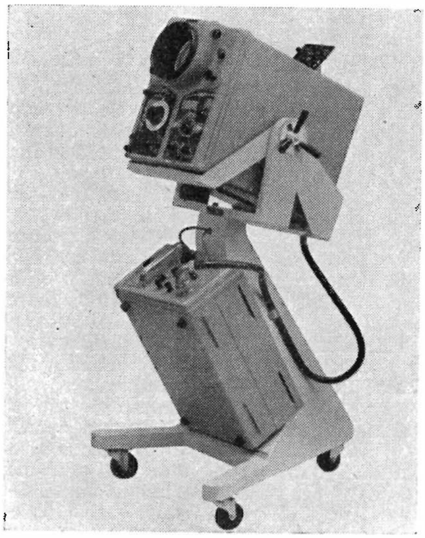
H. V. BECK.

A Simple Frequency Comparison Circuit, as described in Mr. Beck's letter



ELECTRONIC EQUIPMENT

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



Nagard Oscilloscope Trolley

(Illustrated above)

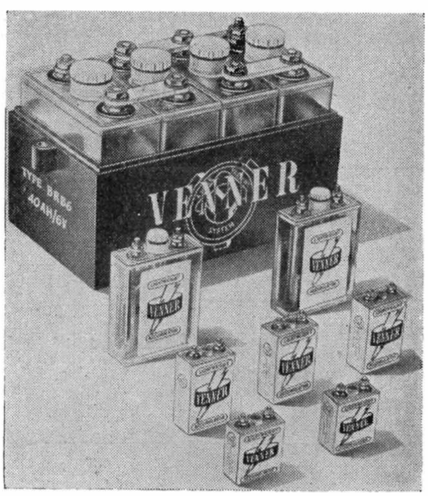
DESIGNED specifically for mounting the Nagard wide range calibrated oscilloscope type 103 in a convenient and mobile form, this trolley is sturdily designed, but of light construction.

It has a triangular base, fitted with ball bearing castors, which gives three point support on uneven floors with stability. It is made entirely of steel, and has a wide adjustment of the viewing angle of the oscilloscope so that the observer can either sit or stand. A three arm locking handle secures the oscilloscope firmly at the desired angle, while even if the handle is released the instrument swings to a horizontal position without shock or damage.

The power unit is supported at its base on the standard rubber feet and prevented from sliding forward by a rail attached to the trolley base. At the upper end a clip is provided on the case of the power unit which engages with a tongue attached to the pedestal. Both units are readily removable when required for use in other conditions.

Connexion to the main electrical supply is provided by a standard sunk three-pin socket situated at floor level, a lead being brought up the hollow pedestal to serve the power unit. The multi-core cable serving the oscilloscope is clipped to the pedestal and to the adjustable cradle so that all strain on the cable terminating plugs is avoided when the viewing angle is adjusted.

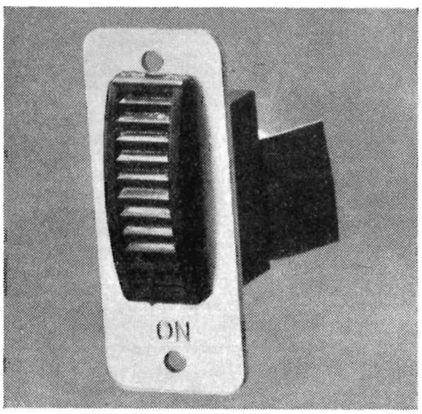
Nagard, Ltd.,
245 Brixton Road,
London, S.W.9



New Arcolectric Switch

ILLUSTRATED below is Arcolectric's new slide thumb switch, rated 3 amps. 250 volts. The switch has a smooth O.M.B. action. Almost flush, it harmonizes with modern designs of portable tools and other small appliances.

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



Venner Accumulators

(Illustrated left)

THE Venner lightweight, alkaline accumulators are based on the silver-zinc reaction.

The advantages of these accumulators are: that they can be stored indefinitely in a discharged condition; they are about half the size of accumulators of similar capacity, and weigh about one-third to one-fifth that of comparable capacity. The strength of the accumulators is only limited by the strength of the case, and the makers claim that they will permanently withstand impact.

The accumulators have an amp./hour efficiency of well over 90 per cent. The operating voltage of each cell is approximately 1.5V, and the accumulators are normally available in sizes up to 40A/H at 12V. The maintenance is negligible, since topping up is only required at infrequent intervals, and there are no corrosive fumes or spray.

Venner Accumulators, Ltd.,
Kingston By-Pass,
New Malden, Surrey.

Automatic Frequency Monitor

THIS instrument has been designed for the measurement of frequency within the range 0-1Mc/s, and is suitable for any shaped waveform of amplitude 10-15 volts R.M.S. providing that it does not pass through the origin more than twice per cycle.

The instrument consists essentially of a crystal controlled oscillator providing selectable time intervals of 0.1, 1.0 or 10 seconds which control the "open" period of an electronic gate. The unknown frequency is passed through this gate into six decade units in cascade and these decades count the number of cycles passing through the gate during its "open" period. Six panel meters scaled 0-9 indicate the value of the frequency measured which will be cycles per second, tenths of cycles per second or tens of cycles per second according to the timing interval used. On the 0.1 and 1.0 second timing ranges an automatic reset unit can be switched into circuit which, on the completion of a count, leaves the result displayed for a convenient reading time and then clears all the dials to zero, whereupon recounting takes place. Thus a continual indication of the frequency being measured is obtained.

The accuracy of the equipment is ±0.005 per cent, ±0.01, 1.0 or 10 cycles/second, according to the timing interval used.

Cinema-Television, Ltd.,
Worsley Bridge Road,
London, S.E.26.

Teledictor A.C. Solenoids

(illustrated below)

THE Teledictor A.C. Solenoid is particularly suitable as an actuator for the control of an operation originated by an electronic timer or other similar device.

The model A.125 is the normal standard, and the model B.125 is the same unit but fitted with an end cheek having an additional bracket on which a separate piece of equipment requiring actuation can be mounted. Either unit, if required, can be fitted with hold-on contacts for interlocking on automatic sequence applications. High efficiency is obtained by the design of the magnetic

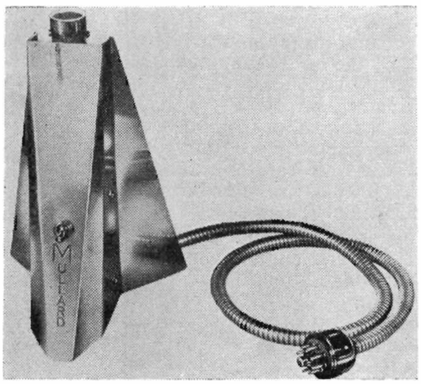
circuit and the use of a high resistivity non-magnetic nickel-chrome alloy for the plunger guides, which also ensures free running and the long life of the moving parts.

These units can be supplied for use on all A.C. voltages ranging from 100 to 500 at normal supply frequencies. Electrical connexions are completely enclosed and made through a $\frac{3}{4}$in. conduit entry.

The physical dimensions of the A model are approximately 4in. by $3\frac{5}{8}$in. by $3\frac{5}{8}$in., and the plunger has a maximum stroke of $1\frac{1}{4}$in.

The unit has a gross pull at 85 per cent line voltage of 15lb.

Teledictor, Ltd.,
214 Birmingham Road,
Dudley, Yorks.



Ultrasonic Soldering Bath

(Illustrated above)

THE rapid tinning of small aluminium and aluminium alloy articles is made possible by an ultrasonic soldering bath recently introduced by the Equipment Division of Mullard, Ltd. This unit has been specifically developed for the soldering of small and complex shaped parts which cannot easily be handled by the Mullard ultrasonic soldering iron. Included in this category of work are such items as foils, wire and tubes.

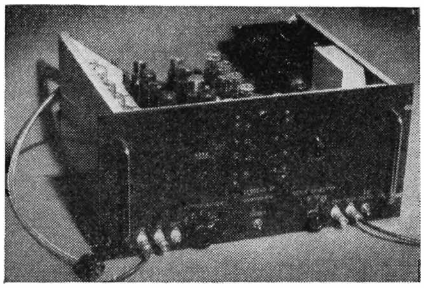
The new soldering bath has been designed to operate from the same power supply unit normally supplied for use in conjunction with the Mullard ultrasonic soldering iron. It consists of a small soldering bath $\frac{7}{8}$in. diameter and $\frac{3}{8}$in. deep. This is heated by means of a conventional resistance winding, and the molten solder in the bath is agitated ultrasonically, at about 20kc/s, by means of a magnetostriction transducer composed of a stack of iron alloy laminations. A control switch on the front of the unit enables the ultrasonic energy to be applied at will.

The dimensions and weights of the units comprising the equipment are:

soldering bath
6in. by 6in. by $9\frac{1}{2}$in. 4lb.
supply unit
9in. by 10in. by 12in. 40lb.

Soldering baths employing larger transducers and operating from higher powered ultrasonic generators can be supplied.

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



Electronic Scaling Unit

(Illustrated above)

THE function of the Labgear scaling units is to count and mechanically register random pulses received at the input over a period of time.

The design incorporates two electronic scale-of-ten units of the Eccles-Jordon type having four neon indicators per unit, followed by a standard G.P.O. mechanical counter of four digits suitably modified for high speed operation. This enables a count of six figures to be registered.

Facilities are provided for counting activity from an ionization chamber via a pre-amplifier drawing its power supplies from the scaling unit, or from a self-quenching geiger-muller tube, which may be directly connected to the input of the scaling unit or through the separate pre-amplifier.

Counting time is controlled through the count-relay, operated either by the count key or an externally connected timing device. Resetting of the electronic circuits is accomplished via the reset-relay, normally operated by the spring loaded reset switch, but capable of control by external means if required.

Routine testing of the instrument is facilitated by a " built-in " pulse generator test circuit having two frequencies of operation.

Labgear, Ltd.,
Willow Place,
Fair Street, Cambridge.

Ediswan Stabilized Power Supply Unit

(Shown above right)

THE Ediswan Stabilized Power Supply Unit is a simple unit which is designed to meet the demand for a reliable stabilized D.C. supply source.

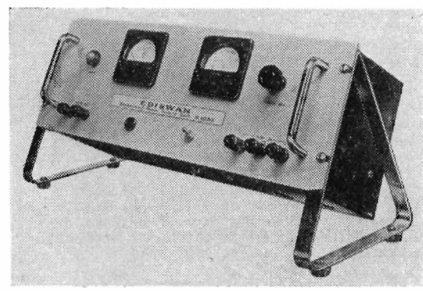
The unit operates on 200-250 volts 40-100 cycles A.C. supply, and provides two outputs: an adjustable 120-250 volts D.C. highly stabilized output capable of supplying a load current of 0-50mA, and a 3.15-0-3.15 volts, 3 amps A.C. unstabilized output.

Connexion to either output is effected by means of 2BA insulated terminals which also accept 3mm resilient plugs. The D.C. output is completely isolated and either the negative or the positive side may be earthed.

The stability of the D.C. output is such that with a mains change of 10V output change is less than 0.1V. With a load change of 0.50mA output change is again less than 0.1V. Output is controlled by reference to a neon stabilizer type KD60.

The standard model is constructed for 19in. rack mounting, and is supplied without meters. The panel is drilled but fitted with a cover plate to permit the addition of meters at any time. Bench stands (as illustrated) are also available.

The Edison Swan Electric Co., Ltd.,
155 Charing Cross Road,
London, W.C.2.



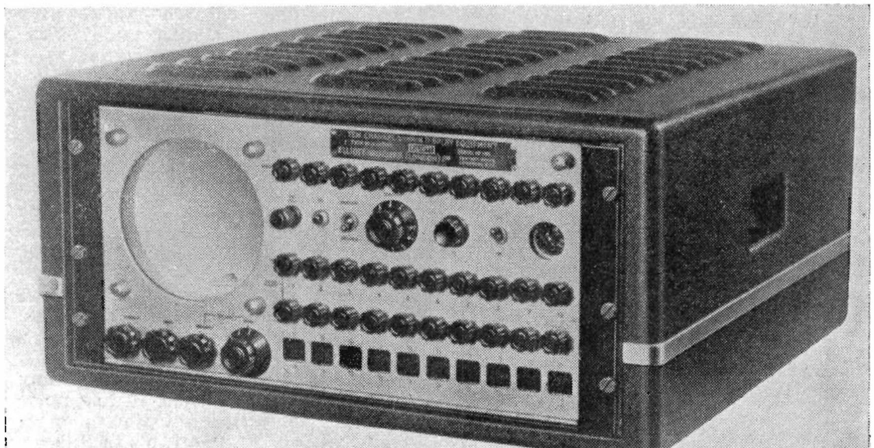
Ten Channel Strain Gauge Display Equipment

(illustrated below)

THIS equipment has been developed for the analysis of complex problems of dynamic strain. By a new method of using pulse excited bridges the amplitude or waveform of strain at 10 different points in a test piece is displayed simultaneously on a single cathode-ray tube.

This unit is self-contained and is suitable for use in the research laboratory, in aircraft or moving vehicles.

Elliott Brothers (London) Ltd.,
Century Works,
London, S.E.13.



BOOK REVIEWS

Time Bases Scanning Generators

By O. S. Puckle, M.B.E., M.I.E.E. 387 pp., 257 figs. 2nd Edition revised. Chapman & Hall, Ltd. 1951. Price 30s.

THE first edition of this book has been very widely read by those to whom the appeal of circuitry is strong, and it is therefore very pleasing to see a second edition appear, with so much added, particularly that dealing with war-time developments.

Of course, when seeing any new edition the reader always looks for material which is of particular interest to him and felt to be missing or poorly covered in the previous edition. As all technical books must be a compromise, particularly now, it is unlikely to be completely satisfying to all. However, in many ways this book does satisfy the reviewer. It covers a large field, and is well written in an easy and interesting manner and deals authoritatively with a subject which is so closely associated with the author.

The book starts with early time bases as time measuring devices, such as the sun dials and water jars of 3,000 years ago, and continues with the more modern ones which generate a voltage or current whose amplitude varies in a controlled manner with time. The first of the type shown is the simple neon circuit, and is followed by the gas filled relay or "soft" valve. Then comes a number of "hard" valve circuits, including the author's own. This chapter is particularly interesting as the very bones of such circuits are exposed and discussed, and the special, and generally ingenious ways of achieving certain results are made clear. Blocking oscillator circuits are dealt with in Chapter VI, and a description is given of the classic magnetic time base of A. D. Blumlein, and the one, due to him and E. L. C. White, using energy recovery. These are practically the only magnetic time bases described, and occupy less than four pages. No mention of other types, such as the single valve self drive types, are made. Time bases of special types such as Polar, Velocity Modulated, and Radial (including the P.P.I. system used in radar displays) are then briefly mentioned.

Chapter VIII is useful and up to date, covering a number of methods of linearizing, followed appropriately by methods of measuring linearity.

Chapter IX deals with circuits using the Blumlein Integration principal to obtain linear voltage changes. This type of circuit has had great application and was generally called a Miller Time Base. The author heads the chapter "Miller—Capacitance Time Bases" but refers in the text to condensers and resistances. It would be tidier to use capacitors and resistors, but it is a good chapter and together with the part of Appendix IV entitled "The Miller—Capacitance Integrator," with the illustration of a circuit called "Blumlein's Miller—capacitance integrator" covers the subject very well indeed. As in the rest of the book, the mathematics are reduced to the minimum. Push-Pull Deflexion follows, using one or more valves, and is interesting and up to date. The reasons for push-pull are given and some of the circuits, such as the "See-Saw", are dealt with in some detail.

Then a short chapter on Synchronizing is followed by one dealing with divider circuits so developed and successfully exploited by Prof. F. C. Williams and his team during the war. Throughout the book there is continual reference to A. D. Blumlein, E. L. C. White, F. C. Williams and N. F. Moody, and it is remarkable how they have so advanced the technique of circuitry. However, are dividers time base or scanning generators, even if they are sometimes alike electrically?

After this chapter comes Appendix I-VIII, which contains useful information, much of which, in the reviewer's opinion, could have been left out of a book of this title, such as a fairly detailed description of electrostatic C.R.Ts including a double beam tube, power supplies for them, brightness modulation, shift circuits, cathode follower probes and fluorescent screens. It is thought that the space would be much better occupied by details of magnetic time bases, particularly as they are now so widely used, and have such special problems. There is not even one illustration of a scanning coil or indication how a magnetic field is generated and made to deflect on electron beam. The Appendix does, however, contain a good summary of *R.L.C.* networks used in waveform generators.

Some circuits covered by the title are not included at all such as beam switches to give multi-traces and those to indicate valve characteristics, *BH* curves and the like.

The circuit diagrams are of a very poor standard for a book which depends so much on their clarity. There are no "envelopes" round the valves and this omission makes some of the circuits look very complicated indeed, and serves no useful purpose. It would also be helpful if some waveforms were given on the circuit diagrams themselves. As it is they are either not given at all, or appear on another page. A few minor errors were noticed. On p. 359 V_1 and V_2 are shown as diodes but are marked EA50 or VR91 while on p. 49 Fig. 31 the anode waveform of V_2 is upside down or is the anode waveform of V_1.

The book is almost certainly the best of its type, and, even more than the first edition, which was translated into French and Dutch, will be of the greatest help to those engaged on, or interested in, such circuits, or to those who wish to become familiar with valves as other than linear amplifiers.

C. H. BANTHORPE

Fractional Horse Power Motors

By S. F. Philpott. 367 pp. Chapman & Hall. 1951. Price 52s.

THIS book contains lucid descriptions of most types of small motors. Prolific illustrations clearly show the essential features of the various types of motor and the way in which manufacturers adapt them for specific duties. Mathematical analysis has been eliminated, and pure design information has been given only in that section covering rewinds for a changed voltage of supply. Naturally, much of the information given in the book applies equally well to larger machines.

In the section on testing a little more might have been said on the subject of loading exceptionally small motors running at high speed. The author limits his remarks to mass-production testing and points out the error arising from air drag on an eddy current disk. By mounting the motor and disk on a balanced tilting platform, the reaction torque on the frame gives the complete information. This method is particularly useful for testing single motors and for obtaining the relationship between air drag on a disk and the speed. With disks thus calibrated, the error in the eddy disk method can be eliminated when testing motors with the frame stationary. An accurate test can often be made with a disk and movable permanent magnet by exercising a little ingenuity in assembling a simple framework on which to balance the motor and thus avoiding the use of a separate loading generator with swinging field.

Only minor criticism can be levelled at the text. For instance, the test circuit shown in Fig. 14.6 merits further consideration. As 2-pin plugs are usually reversible, the reversing switches seem redundant and a point of measurement technique seems to have been overlooked. It is preferable to reverse the current coil of a wattmeter rather than the pressure circuit, particularly when high voltage multipliers are used.

The author and the publishers have co-operated to produce an excellent descriptive book which provides a most valuable counterpart to the analytical treatment which looms so large in professional electrical training. This particular book should appeal to all those who seek information about small motors, whether they be electrical engineering students, test room assistants or electricians.

A. P. JARVIS

Gas Discharge Lamps

By J. Funke and P. J. Oranje. 288 pp., 110 tables and graphs. 82 photographs. Cleaver Hume Press. 1951. Price 30s.

THIS book, one of the Philips Technical Library series, was originally written by Mr. Oranje and published on the Continent in 1941. The present edition has been revised and re-written by Dr. Funke, new material being included and older material brought up to date. It is wide in scope and thorough in treatment. From a general review of the fundamental physical processes of the gaseous electric discharge and its stabilization by various types of auxiliary control apparatus the book passes to a detailed account of the various types of sodium vapour, mercury vapour and fluorescent lamps in general use today. Various special lamps, including stroboscopic and flashing types, are also dealt with, but others, of limited application and broadly classified as negative-glow types, have been deliberately excluded. The book is well illustrated with photographs of lamps, equipment and installations, and there are numerous well-executed line drawings and graphs.

The general reader may with confidence turn to this book for information and will find the subjects covered effectively and clearly. Some of the latest material will be of interest to the more specialized reader also. Although particular stress has been placed on lamps made by N.V. Philips Gloeilampenfabrieken, Eindhoven, and their applications, general descriptions and discussions ensure that the treatment is not unbalanced in the whole. A short list of books for further reading on gas discharge lamps is given for the general reader, but those seeking more specialized knowledge in particular fields may wish that the longer bibliography of scientific papers and articles had not been confined to those emanating from this one commercial undertaking.

N. L. HARRIS

Theory and Application of Industrial Electronics

By J. M. Cage. 290 pp. + xi. 1st edition. McGraw-Hill Book Co. Inc., 1951. Price 40s. 6d.

THIS is one of the well-known McGraw-Hill Electrical and Electronic Engineering series edited by Terman, and as such must command our attention and perhaps respect. One wonders, however, if yet another general book on industrial electronics is needed at this stage of the art. Perhaps a justification is that it is useful to find between two covers all those branches of electronics that have industrial applications. This book is an advance on its predecessors as an attempt has been made, as the preface states, to develop a set of concepts, basic circuits and sound techniques to serve as general tools. The attempt is successful and the book is of a more lasting and general nature than many which have been current in the last few years. The presentation is interesting and practical as the theory and application of each topic is considered as a complete unity in a logical order going through rectifier circuits, amplifiers, regulators and servomechanisms, electronic control, timing circuits, welding control, induction and dielectric heating, measurements, oscillators and pulse techniques. The usual and indispensable miscellaneous chapter covers electrostatic precipitation, X-rays and stroboscopes. The chapter on measurements is disappointing since it does not significantly mention industrial electronic instrumentation—the measurement and recording of *p*H, moisture, level, pressure and the hundred and one other physical and physico-chemical criteria requiring attention in modern industrial processes. However, in all, the book includes items which are adjuncts to conventional industrial equipment and

BOOK REVIEWS (Continued)

those which do a useful job in their own right.

The style is clear and workmanlike with a fair sprinkling of mathematics of about degree standard. Most chapters are followed by problems serving to underline the foregoing matter and focus attention on important points. There are plenty of literature references, drawings and photographs, the last naturally relating to American practice.

The author excels on those points where industrial electronics differs from its progenitors—classical electrical engineering and radio communication; and preserves a lively sense of scale in many discussions, realizing that the levels of power, voltage and current in industrial practice are usually higher than in other and, perhaps to most readers, more familiar applications. The economic side is not neglected and is introduced both in regard to prime cost and running expenses of equipment.

The volume can be confidently recommended to the student whose previous knowledge covers electrical and radio engineering and to those more experienced engineers wishing to brush up on this rapidly expanding field of applied physics. It is produced in typical American style with that familiar glossy appearance and a new binding of lively dignity. Its price is high, too high, but that is a contemporary disease, and the book should have a good circulation among borrowers.

E. D. Hart

Institution of Electrical Engineers

Heaviside Centenary Volume

98 pp. December, 1950. Institution of Electrical Engineers. Price 10s. 6d., or 4s. to members of the I.E.E.

THIS well-produced volume recording the recent I.E.E. Heaviside Centenary Proceedings makes a valuable addition to our somewhat scanty knowledge of that remarkable genius, Oliver Heaviside, whom Dr. Sumpner described in his Kelvin Lecture as "a mathematician at one moment, and a physicist at another, but first and last and all the time a telegraphist."

The volume contains papers by Sir Geo. Lee, H. J. Josephs, Professor Willis Jackson, Professor Balth von der Pol, Dr. W. G. Radley, Professor Harold Jeffreys, and a personal sketch by Dr. G. F. C. Searle, who without doubt was the closest of Heaviside's scientific friends, having known him from 1892 and visited him annually until the year of Heaviside's death in 1925. In addition there are shorter contributions by such men as Sir Edward Appleton and others.

Thus, it will be realized that the standard of articles is high, each author having a distinct contribution to make in his own field.

Some of the personal touches make one realize how difficult it must have been for friends to collaborate with Heaviside, witness the stifling hot atmosphere of the unventilated room, heated by gas fires, and filled with clouds of tobacco smoke.

As time rolls on, however, and all the clouds of controversy disperse, Oliver Heaviside's influence on the progress of mathematical and physical science is surely bound to be increasingly appreciated.

J. T. MacGregor-Morris

Fundamentals of Acoustics

By L. E. Kinsler and A. R. Frey. 516 pps. 1st Edition, 1950. John Wiley and Sons, Inc., New York. Chapman and Hall Ltd., London. Price 48s.

THE authors of this book are both Professors of Physics at the United States Naval Post-Graduate School, Annapolis, and the book has been written to a standard suitable for students of acoustics, a knowledge of mathematics appropriate to such individuals being assumed, for example the solution of differential equations and Fourier analysis.

The word 'Fundamentals' in the title might mislead some people as to the scope of the book. Fundamental theory is dealt with in the first nine chapters only, the remaining seven being devoted to various applications of acoustics. The correct interpretation of the word as used here, is that in each chapter general theory takes first place, practical examples being used in moderation as illustrations. The decimal system of notation is used for chapter sub-headings, equations, figures, and for the problems which appear at the end of each chapter. The latter serve a most useful purpose. The text is amply illustrated with graphs and diagrams.

The first chapter is more comprehensive than its title 'Simple Harmonic Motion' implies, since it deals with all aspects of vibration in general, including electro-mechanical coupling.

The next three chapters are concerned with vibrating strings, bars, membranes and plates. The authors have borne in mind the close analogy that exists between wave transmission in the fields of sound and electricity, and so it is not surprising to find that much of the chapters on acoustic plane waves, transmission phenomena, resonators and filters could be included without alteration in an Electrical Communications Handbook.

Chapters seven and nine deal with spherical acoustic waves and the absorption of sound waves.

The last seven chapters on the various applications are concerned respectively with direct radiator loudspeakers, horn type speakers, microphones, psycho-acoustics, architectural acoustics, under water acoustics and ultrasonics. Any criticism that could be made would be of a minor nature, for example in the subsections on the cone speaker and loudspeaker cabinets, the authors' explanations of how these units operate are not as convincing as they might be. A better approach would be to show how the required response could be produced with ideal components and then discuss practical limitations. The chapter on architectural acoustics would be more complete if it contained a section on the use of resonant absorbers.

The book ends with an Appendix of miscellaneous tables and a Glossary of symbols which are in accordance with the American Standards Association.

Although the ground has all been covered before in other books, the presentation of the subjects here make it an excellent book of its kind.

R. O. Rowlands

Radio Valve Data

80 pps. Iliffe & Sons Ltd. for "Wireless World." July, 1951. Price 3s. 6d.

The new edition of this reference book contains the main characteristics of over 2,000 types of British and American radio valves, and over 100 cathode-ray tubes.

The main tables give the electrical characteristics of each valve, and separate tables show their base connexions. Subdivisions of the main tables further classify the valves into obsolete, replacement or current types, as recommended by the makers. An index enables any valve to be found in the tables quickly and without trouble.

The following classes of valves are included: frequency-changers, screened tetrodes and pentodes, output valves, diodes, output valves and efficiency diodes for television live scan circuit, amplifier triodes, transmitting valves of various types up to 50 watts anode dissipation, valve rectifiers, E.H.T. rectifiers, tuning indicators, barretters, voltage stabilizers and thyratrons. In addition, non-thermionic diodes of the silicon, germanium and selenium types are listed, and also metal rectifiers. The cathode-ray tube section covers all British tubes for television receivers and oscilloscopes.

Television Explained •

By W. E. Miller. 104 pps. 59 figs. 16 photographs. 4th Edition. Trader Publishing Co. Ltd. June, 1951. Price 5s.

THIS book gives a testimony of its popularity by reaching a fourth edition, and it is addressed to those people having some knowledge of radio circuitry, who are interested similarly in television.

The author uses a straightforward and simple style, and the text is non-mathematical. The book is well illustrated, and a useful feature is the inclusion of a series of actual photographs of picture faults, with a note on the appropriate remedy to be applied in each case.

There is a helpful chapter on receiver installation and maintenance, and recent information on the television frequencies to be used by the B.B.C. is incorporated. A note on the new synchronizing circuit has also been added.

Chapter headings include: Aerials, The Signal, Sync Separation, Scanning Circuits, Deflexion Amplifiers, and Power Supplies.

NOTES FROM THE INDUSTRY

Brit. I.R.E. Premiums and Examination Awards for 1950. The senior award of the Brit. I.R.E., the Clerk-Maxwell Premium, will be awarded to D. W. Heightman (now with the English Electric Co., Ltd.) for his paper on "The Propagation of Metric Waves beyond Optical Range." This Premium is for the most outstanding paper published in the Institution's Journal during the year 1950. The award will be made at the annual general meeting.

Other 1950 awards which will be presented at the same time, and which have just been announced by the General Council of the Institution are as follows:—

Rudolf Kompfner, Dipl.Ing. (The Clarendon Laboratory, Oxford) will receive the Heinrich Hertz Premium for his paper "On the Operation of the Travelling Wave Tube at Low Level," which appeared in the August/September 1950 issue of the Journal.

The Louis Sterling Premium will be presented to J. E. B. Jacob, B.Sc. (Cinema Television, Ltd.) for his paper on "High Performance Television Monitors" which was published in the April 1950 issue of the Journal.

S. W. Punnett, B.Sc. (University College, Southampton) will receive the Dr. Norman Partridge Memorial Award for his paper "Audio Frequency Selective Amplifiers," published in the February 1950 Journal.

In addition, the following examination prizes will be awarded:—

The Electronic Measurements Prize to:—

P. W. Abbott (Post and Telegraphs Department, Tripoli), the most outstanding candidate in the subject of Electronic Measurements during 1950.

The Audio Frequency Engineering Prize to:—

J. D. Simmonds (Bonochord, Ltd.), the most outstanding candidate in the subject of Audio Frequency Engineering during 1950.

Holme Moss—High Power Tests. Test transmissions on full power from the new B.B.C. television transmitting station at Holme Moss, which is to be opened by the Postmaster General on October 12, 1951, were started on September 3.

The tests took place each morning between 10 a.m. and 12 mid-day (excepting Sundays) until September 10. After this they were extended to include the afternoon programmes as advertised in the Radio Times. The morning transmissions are composed of film with periods of test card, Mondays to Fridays; on Saturdays a test card pattern is transmitted between 10 a.m. and 11 a.m. followed by a newsreel from 11 a.m. to 12 noon.

The tests are for engineering purposes and may be subject to interruption, variation in power, and alteration of times. Whenever possible, however, notice of changes in the schedule will be given.

The transmitter may also radiate at other times, but such transmissions may not be representative of normal conditions. They should not, therefore, be used for checking receiver performance.

The R.E.C.M.F. Exhibition, 1952. The ninth annual private exhibition of British components, valves and test gear for the radio, television, electronic and telecommunication industries, will be held in the Great Hall, Grosvenor House, Park Lane, London, W.1, during the period Monday, April 7 to Wednesday, April 9, 1952.

Admission will be by invitation only. Further details will be issued in due course by the organizers, the Radio and Electronic Component Manufacturers' Federation, 22 Surrey Street, Strand, London, W.C.2.

A course of 24 evening Lectures on Communication Networks. Lectures on communication networks will be given by Dr. W. Saraga, Ph.D., at the South East London Technical College commencing on October 23. The fee for the course is £1, and the series will cover mathematical techniques, two-terminal networks, four-terminal networks, attenuation networks, attenuation equalizers, time delay networks, wide-band phase splitting networks, image parameter filters and insertion parameter filters.

Another evening course, on high voltage engineering under the direction of Professor W. J. John, with Dr. T. J. Lewis, Ph.D., B.Sc.(Hons.), will commence on October 9. It will include practical laboratory periods to be carried out at Queen Mary College, Mile End Road, London, E.1, and the lectures will take place at the South East London Technical College. Full details of both courses can be obtained from the Head of the Electrical Engineering Department, Lewisham Way, London, S.E.4.

British Standard for Graphical Symbols used in Waveguide Technique. (Supplement No. 2, 1951 to B.S. 530). Graphical symbols are included relating to most of the concrete items defined in Supplement No. 1 to B.S. 204, Glossary of Terms used in Telecommunication, which are suitable for circuit diagrams and installation diagrams both in the single and double line forms. The former are mainly based on the standard symbols published in America by the Institute of Radio Engineers.

Copies of this standard may be obtained from the British Standards Institution, Sales Department, 24 Victoria Street, London, S.W.1, price 3s. post free.

First Electrical Engineers Exhibition. The recent success of the North West London Branch of the Association of Supervising Electrical Engineers' Exhibition is mainly responsible for the planning of a national exhibition which is to be held on March 28 and 29, 1952, at the Royal Horticultural New Hall, London, S.W.1.

The main theme of the exhibition is to be simplicity and economy due to the present conditions, and no elaborate stands are considered necessary. Working exhibits will be encouraged, especially any labour saving equipment, safety devices and peak load saving ideas.

Invitations to Government departments and the trade will be available. Electrical manufacturers interested should get in touch with the Exhibition Secretary, P. A. Thorogood, 35 Gibbs Green, Edgware, Middx.

B.B.C. Engineering Division Appointment. In view of Mr. H. L. Kirke's prolonged absence on sick leave, it has been decided to appoint Mr. F. C. McLean, H.E.P.G., as acting assistant chief engineer.

He has taken over Mr. Kirke's work of co-ordination and direction of the technical work of research department, planning and installation department, designs department and equipment department.

British Standard for Enamelled Round Copper Wire (Oleo-Resinous Enamel) (B.S. 156:1951).—The new edition of B.S. 156 is entitled "Enamelled round copper wire (oleo-resinous enamel)," and it differs from the 1943 edition in that it has been extended to include the full range of wire sizes from 0.001in. to 0.160in. inclusive. It gives details of diameters, resistances, and thickness of enamel (including tolerances), together with tests on the enamel insulation. These tests relate to hardness, flexibility and adherence, heat shock, cold test at 0°C, heat ageing and electric strength. The standard sizes of wires complying with this specification are given in S.W.G., and in an appendix are given details of a range of wires complying with Brown and Sharp gauges.

Copies of this standard may be obtained from the British Standards Institution, price 3s. post free.

Electronic Equipment. In the "Electronic Equipment" columns of the August issue there appeared several errors, for which we apologize. In the paragraph headed "Miniature Standard Cell" line six should read "cadmium cell of the saturated acid type" and line ten "comparable with those of normal type." In the account of the miniature transformers made by John Bell and Croyden the polarizing current shown in the second paragraph as 200 milliamps and 1,000 milliamps respectively, should read microamps.

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, at 5.30 p.m.

Date: October 11.
Inaugural Address of the President.
By: Sir John Hacking.

Radio Section

Date: October 12. Time: 5.30 p.m.
Informal lecture: Recent Developments in Transistor Electronics.
By: W. Shockley, Ph.D., B.Sc.
Date: October 17.
Address of the President.
By: D. C. Espley, O.B.E., D.Eng.
Date: October 29.
Discussion: The Social Implications of Television.
Opened by: F. H. Townsend.

Measurements Section

Date: October 23.
Address of the President.
By: F. J. Lane, O.B.E., M.Sc.

District Meetings

Date: October 8. Time: 7.30 p.m.
Held at: The Royal Hotel, Norwich.
Lecture: Some Electrical Methods of Measuring Mechanical Quantities.
By: F. J. Woodcock.
Date: October 10. Time: 7 p.m.
Held at: The Electricity Showrooms, 37 George Street, Oxford.
Lecture: Radar Principles and Application.
By: Professor A. Lee, M.A.

Cambridge Radio Group

Date: October 16. Time: 6 p.m.
Chairman's Address.
By: G. C. Greenwood.

North Eastern Radio and Measurements Group

Date: October 15. Time: 6.15 p.m.
Held at: King's College, Newcastle-on-Tyne.
Chairman's Address.
By: W. W. Campbell, B.Sc.

North Western Measurements Group

Date: October 16. Time: 6.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: Performance Limits in Electrical Instruments.
By: A. H. M. Arnold, Ph.D., D.Eng.
Lecture: The Accuracy of Measurements of Electrical Standards.
By: A. Felton, B.Sc.(Eng.).

North Western Radio Group

Date: October 24. Time: 6.30 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Chairman's Address.
By. Professor F. C. Williams, O.B.E., D.Sc., D.Phil., F.R.S.

South Midland Centre

Date: October 23. Time: 7.15 p.m.
Held at: The Winter Gardens Restaurant, Malvern.
Lecture: The Determination of Time and Frequency.
By: H. M. Smith, B.Sc.

South Midland Radio Group

Date: October 22. Time 6 p.m.
Held at: The James Watt Memorial Institute, Gt. Charles Street, Birmingham.
Address by the Chairman of the Radio Section.
By: D. C. Espley, D.Eng.

Southern Centre

Date: October 10. Time: 7.30 p.m.
Held at: R.A.E. College, Farnborough, Hants.
Discussion on: Electrical Measurement by Thermal Effects.
Opened by: L. G. A. Sims, D.Sc., Ph.D., Professor J. Greig, B.Sc., Ph.D., and J. G. Freeman, M.A., Ph.D.
Date: October 24. Time: 6.30 p.m.
Held at: The Dorset Technical College, Weymouth.
Lecture: The Sutton Coldfield Television Broadcasting Station.
By: P. A. T. Bevan, B.Sc., and H. Page, M.Sc.

INSTITUTE OF PHYSICS

Education Group

Date: October 9. Time: 5.30 p.m.
Held at: The Institute of Physics, 47 Belgrave Square, S.W.1.
Lecture: Experiences in Education in Science in Australia.
By: Professor A. D. Ross, F.Inst.P.

Electronics Group

Date: October 16. Time: 5.30 p.m.
Held at: The Institute of Physics, 47 Belgrave Square, S.W.1.
Lecture: The Physics of Glass.
By: R. W. Douglas, F.Inst.P.

Industrial Radiology Group

Date: October 19. Time: 6.30 p.m.
Held at: The Institute of Physics, 47 Belgrave Square, S.W.1.
Lectures on: The Tenth Anniversary of the Industrial Radiology Group.
Lecture: Looking Forward.
By: W. E. Schall, F.Inst.P.
Lecture: Looking Back.
By: Dr. L. Mullins, F.Inst.P.

Scottish Branch

Date: October 16. Time: 7 p.m.
Held at: The University of Glasgow.
Lecture: Recent Work on the Colour Vision of Men and Animals.
By: Professor H. Hartridge, F.R.S.

North Eastern Branch

Date: October 10. Time: 6.15 p.m.
Held at: King's College, Newcastle-upon-Tyne.
Lecture: Low Temperature Physics.
By: Dr. K. Mendelssohn, F.Inst.P., F.R.S.

Midland Branch

Date: October 18. Time: 7 p.m.
Held at: The Imperial Hotel, Birmingham.
Lecture: The Industrial Application of Ultra-Violet Radiation.
By: Dr. W. Summer, A.Inst.P.

Manchester and District Branch

Date: October 19. Time: 7 p.m.
Held at: The University of Manchester.
Lecture: Cosmic Rays.
By: Dr. G. D. Rochester, F.Inst.P.

South Wales Branch

Date: October 20. Time: 2 p.m.
Held at: University College, Cardiff.
Lecture: Electron Diffraction and Surface Structure.
By: Professor G. I. Finch, M.B.E., F.Inst.P., F.R.S.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: October 2. Time 5 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: Transmission Performance of the Telephone Network—A Survey of Some Basic Problems.
By: J. Swaffield, Ph.D., and D. L. Richards, B.Sc.(Eng.).

SOCIETY OF INSTRUMENT TECHNOLOGY

Date: October 30. Time: 7 p.m.
Held at: Lecture Theatre, Royal Society of Tropical Medicine and Hygiene, Manson House, Portland Place, W.1.
Lecture: Development of Materials for Instrument Manufacture.
By: E. B. Moss.

THE TELEVISION SOCIETY

Date: October 11. Time: 7 p.m.
Held at: The C.E.A., 164 Shaftesbury Avenue, W.C.2.
Lecture: P.O. Cable Circuits for the O.B. Television Service.
By: H. Moore.
Date: October 26. Time: 7 p.m.
Held at: The C.E.A., 164 Shaftesbury Avenue, W.C.2.
Lecture: A Line Strobe Monitor for Measuring and Investigating Television Waveforms.
By: E. Davies.

BRITISH SOUND RECORDING ASSOCIATION

Date: October 19. Time: 7 p.m.
Held at: The Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: Technical Aspects of the B.B.C. Television Film Unit.
By: M. F. Chapman.

SOCIETY OF RELAY ENGINEERS

Date: October 2. Time: 2.30 p.m.
Held at: The E.M.I. Institute, 10 Pembridge Square, London, W.2.
Lecture: Television Relay by Wire.
By: Messrs. E.M.I., Ltd.

RADIO SOCIETY OF GREAT BRITAIN

Date: October 26. Time: 6.30 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, W.C.2.
Lecture: Problems in Amateur Television Transmitter Modulator Design.
By: J. R. Erskine and R. Grubb.

Publications Received

R.C.A. WHAT IT IS—WHAT IT DOES. This attractive brochure has been produced to give the answers to questions often asked about this organization. This booklet gives an insight into the many fields which R.C.A. covers: research, communications, technical training, industry, television, radio, and marine radio. It is published by the Department of Information, Radio Corporation of America, R.C.A. Building, 30 Rockefeller Plaza, New York 20, U.S.A.

SOME NOTES ON THE FORMATION AND UTILIZATION OF FLASH STEAM is an excellent little booklet produced by the Drayton Regulator & Instrument Co., Ltd., of West Drayton, Middlesex. As the cost of fuel makes the conservation of heat of considerable importance, these notes should prove useful in a number of industries. This booklet can be obtained from Drayton's, but requests for copies should be accompanied by 6d. in stamps to cover part cost and postage.

FORTIETH ANNUAL REPORT 1950-51 OF THE BRITISH ELECTRIC AND ALLIED MANUFACTURERS' ASSOCIATION INC. This interesting report of B.E.A.M.A.'s activities shows that the electrical industry is the second largest exporting industry in this country. Its activities included: the endowment of a chair in electrical engineering at the University of Cambridge; the launching of a training scheme for overseas students, in collaboration with the Federation of British Industries; the establishment of the "Athlone Fellowships", and representations to the Ministry of Supply concerning the shortage of materials. Co-operation has been given to the Festival of Britain Authorities and the Council of Industrial Design in the portrayal of electricity in the Festival exhibitions. Copies may be obtained from B.E.A.M.A., 36 and 38 Kingsway, London, W.C.2.

BRITISH IRON AND STEEL RESEARCH ASSOCIATION—ANNUAL REPORT OF THE COUNCIL, 1950. This report includes several sections of interest to our readers, notably those on: open hearth instruments; pyrometry; the work of the electrical engineering committee, and the new techniques committee; the physics department's report and the instrument section. Copies of this report are available on application to B.I.S.R.A., 11 Park Lane, London, W.1.

" CYLDON " VARIABLE CAPACITORS is a catalogue of mica and air dielectric trimmer capacitors manufactured by Sydney S. Bird & Sons, Ltd., Cambridge Arterial Road, Enfield, Middlesex. All models of the standard "Cyldon" range are described and illustrated, which are designed to meet most requirements of radio and electronic equipment, but special type inquiries are welcomed. The catalogue is well produced, with clear diagrams and illustrations, and it can be supplied by Sydney S. Bird, Ltd., to wholesalers and equipment manufacturers only.

WIGGIN NICKEL ALLOYS NO. 330. This recent issue includes articles on concentrating sodium sulphide, water treatment, chemical valves and cocks, belt fastenings, pickling plant, enamelling perrits and methods of tipping carbide tools. Instructions on methods of perforating high nickel alloys are given in a well-illustrated article showing various items produced in monel and nickel. Copies of this publication may be obtained on application to Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham 16.

REPORT OF THE CONFERENCE ON " ELECTRICITY AS AN AID TO PRODUCTIVITY " is the proceedings of the conference on that subject held at the Institution of Electrical Engineers on November 15 and 16 last. The subjects dealt with can be grouped under the following headings: Motive Power in the Factory; Industrial Heating Processes; Welding Applications; The Handling and Inspection of Materials; and Lighting, Heating and Ventilation, etc. Copies of the Report may be obtained, price 6s. post free, on application to the Secretary of the Institution of Electrical Engineers, Savoy Place, London, W.C.2.

PLESSEY VIBRATORS. The Plessey Co., Ltd., of Ilford, Essex, was a pioneer in the manufacture of vibrators in Britain, and has devoted considerable research to their development. A wide range of present-day units is fully described in this brochure, which also points out their many applications. The booklet is well presented, with carefully designed diagrams, and a word of praise must be added for the attractive cover.

AN H.F. ULTRASONIC GENERATOR

FOR RESEARCH LABORATORIES

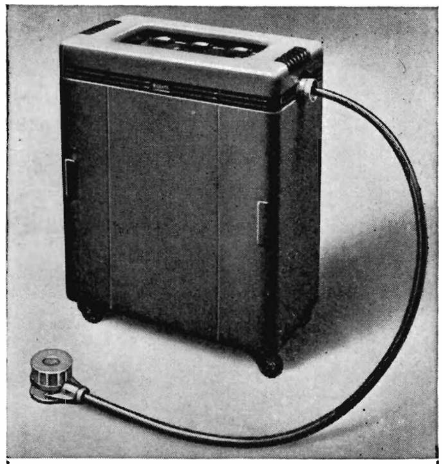
Equipped with special transducer for immersion in conductive liquids

THIS generator has been developed to assist industrial research laboratories in their studies of ultrasonics.

It is capable of providing the highest ultrasonic power outputs within reach of a commercial instrument. And it covers the frequency range in which high intensities can be generated by a quartz crystal.

The transducer can be immersed in conductive liquids. This is a unique feature of the apparatus. All the inconvenience and power loss of operating the crystal under transformer oil is avoided.

The generator comprises a control panel with meters, power oscillator, output voltmeter, relay panel and power supply. It is mounted in a tubular frame. Trolley wheels make it easy to move about, and the cover is adequately ventilated. Mains supply is 230 volts 50 c/s. Power consumption up to 1.5 kilowatts.



The Mullard Ultrasonic Generator, type E.7562. Dimensions : Height 3′. Width 1′ 4″. Length 2′. Weight 2 cwt. 16 lb. Please write for full technical details.

Mullard

NORTHERN AGENT: *F. C. Robinson & Partners, Ltd., 287, Deansgate, Manchester, 3.*
MIDLAND AGENT: *Hadley Sound Equipments, 72, Cape Hill, Smethwick.*
SCOTTISH AGENT: *Land, Speight & Co. Ltd., 73, Robertson St., Glasgow, C.2.*

MULLARD LTD., EQUIPMENT DIVISION, CENTURY HOUSE, SHAFTESBURY AVENUE, W.C.2. TEL: GER. 7777

(MI.347)

Measurements from 30c/s to 10Mc/s

may be made with the

AIRMEC

MILLIVOLTMETER

TYPE 784

THIS instrument consists of a high-impedance probe unit followed by a stable wide-band amplifier and diode voltmeter. Measurements may be made from 1 millivolt to 1 volt in the frequency range 30 c/s to 10 Mc/s. The provision of a low-impedance output enables the instrument to be used as a general-purpose amplifier in the frequency range 30 c/s to 15 Mc/s, or as an extremely sensitive high-impedance pre-amplifier for the Airmec Oscilloscope Type 723.

SPECIFICATION when in use as:

A MILLIVOLTMETER

Input Impedance : 1 Megohm in parallel with 14 pF.
Voltage Ranges : 0–10, 0–100, 0–1,000 millivolts.
Accuracy : 30 c/s–5 Mc/s, ±5% of F.S.D.; 5 Mc/s–10 Mc/s, ±10% of F.S.D.

A WIDE-BAND AMPLIFIER

Output Impedance : 200 ohms.
Voltage Gain : 30 db.
Frequency Response : Less than 6 db down at 15 Mc/s.

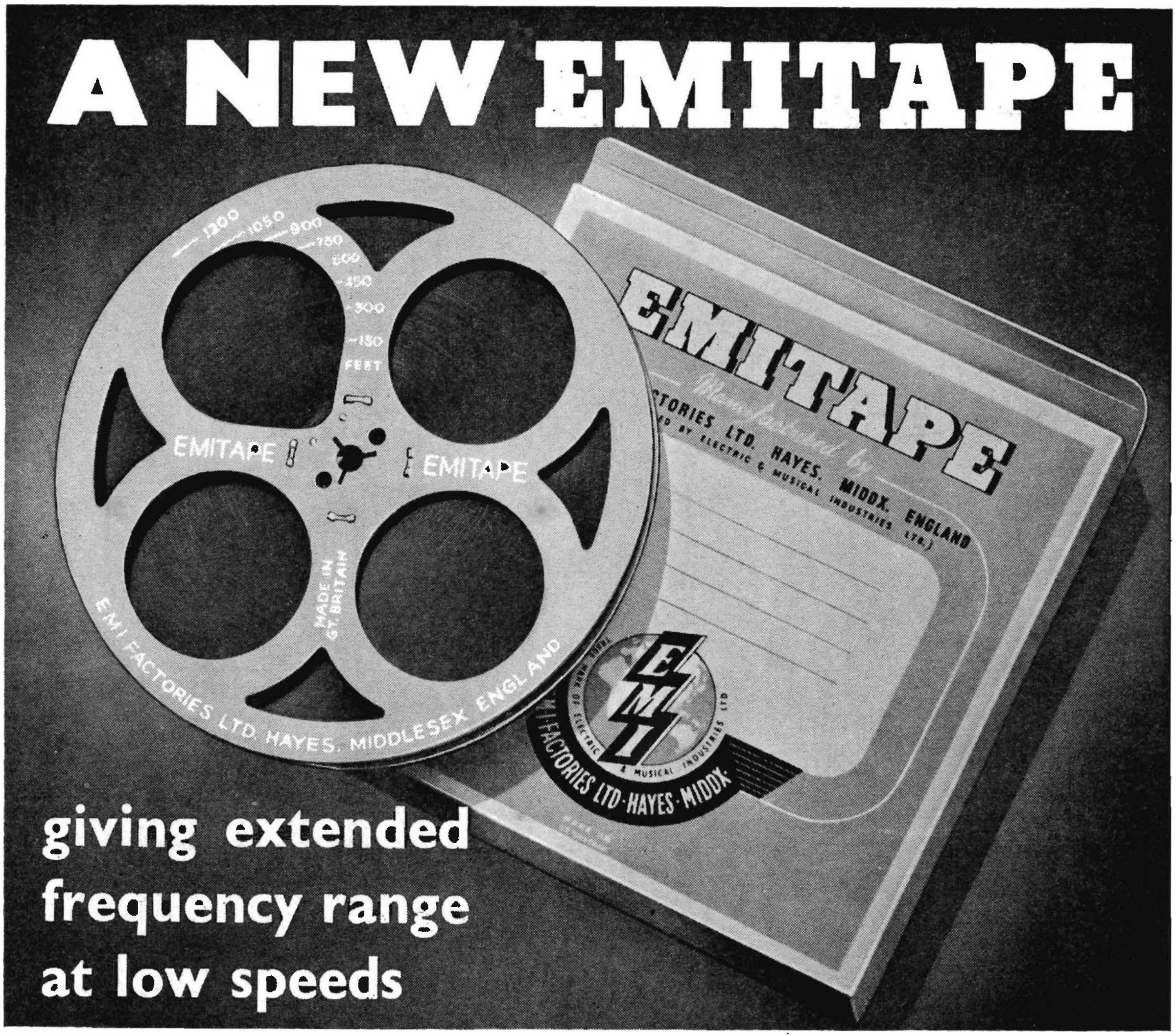
A PRE-AMPLIFIER FOR THE AIRMEC OSCILLOSCOPE, TYPE 723

Sensitivity : 2 millivolts R.M.S. per centimetre at an E.H.T. voltage of 2 kV.
Frequency Response : ±2 db from 30 c/s–5 Mc/s.

AIRMEC
LABORATORIES, LTD.

HIGH WYCOMBE - BUCKINGHAMSHIRE - ENGLAND

Telephone : **High Wycombe 2060** - *Cables* : **Airmec High Wycombe.**



As the result of continued research E.M.I. Factories have introduced an entirely new grade of magnetic recording tape to be added to the present Emitape range.

The new tape, type H.60, has the familiar Emitape plastic base but is coated with a special high coercivity oxide which enables recordings to be made on slow speed machines of a quality hitherto only attainable on high speed professional recorders.

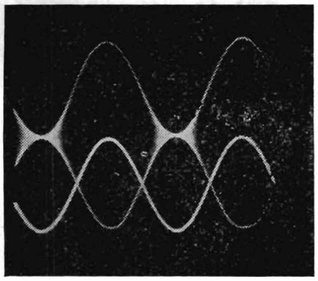
This feature makes it eminently suitable for use on recorders operating at slow tape speeds.

It is supplied on standard reels of 1,200 feet or 600 feet, but larger spools for professional use are also available.

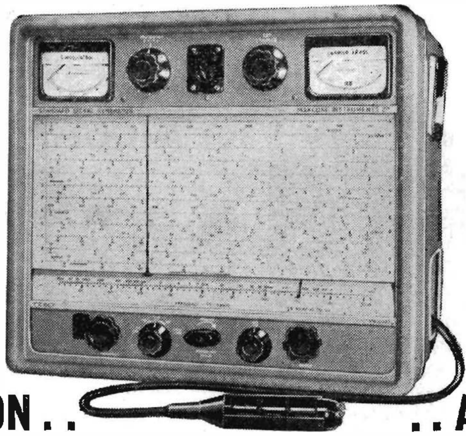
Like the well-known type 65, Emitape type H.60 is obtainable through a limited number of wholesalers. If your supplier is unable to give you full details of both types, write :—

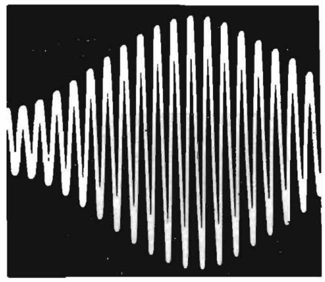
E.M.I. FACTORIES LTD
EMITAPE DEPT., HAYES, MIDDLESEX

B.205a



320kc/s modulated 400c/s; audio on second beam.





24kc/s modulated 60% 1kc/s.

100% MODULATION . . . . A.M. WITHOUT F.M.

Excellent amplitude modulation is a feature of the Standard Signal Generator TF 867 — a.m. accompanied by minimum spurious f.m. — less than 100 c/s below 5 Mc/s, 1000 c/s above. Other features are:

Wide range — 15 kc/s (or less) to 30 kc/s in 11 bands on full vision scale.
Crystal accuracy — 0.01% 1 Mc/s harmonic source built-in.
Easy tuning — discrimination 1 part in 10,000 on total 15 ft. scale length.
High output — 4 volts down to 0.04 microvolts.
Flexible modulation — internal 400 and 1,000 c/s, 0-100%. External 50-10,000 c/s ± 2db.

MARCONI instruments

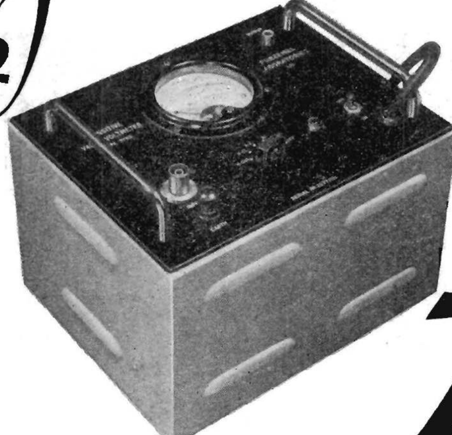
MARCONI INSTRUMENTS LTD · ST. ALBANS, HERTS. · PHONE: ST. ALBANS 6161/7

London Office : Marconi House, Strand, W.C.2. **Midland Office :** 19 The Parade, Leamington Spa. **Northern Office :** 30 Albion Street, Hull.

2

ImV to 100,000mV . . .

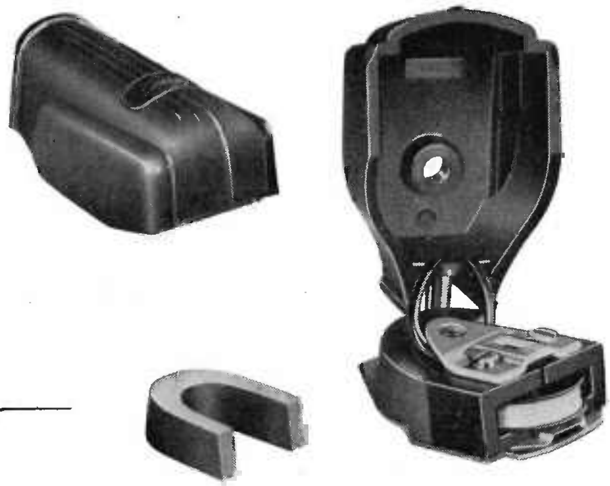
Voltage measurements from ImV to 100V within the frequency range of 10c/s to 500Kc/s can be made with this Sensitive Valve Voltmeter. The logarithmic scale shape of the meter enables an accuracy of ± 5% at all points to be achieved.



Furzehill

FURZEHILL LABORATORIES LIMITED
BOREHAM WOOD, HERTS. ELStree 3940

PERMANENT MAGNETS



A COMPLETE SERVICE—
ADVISORY AND SUPPLY—
FOR SPECIALISED
INDUSTRIES

TOLEDO

Illustration shows a compact gramophone pick-up head utilizing modern Alcomax Permanent Magnet.
(By courtesy of Collaro Limited)

DARWINS LTD

TINSLEY · SHEFFIELD · 9

D27

GARDNERS RADIO Ltd

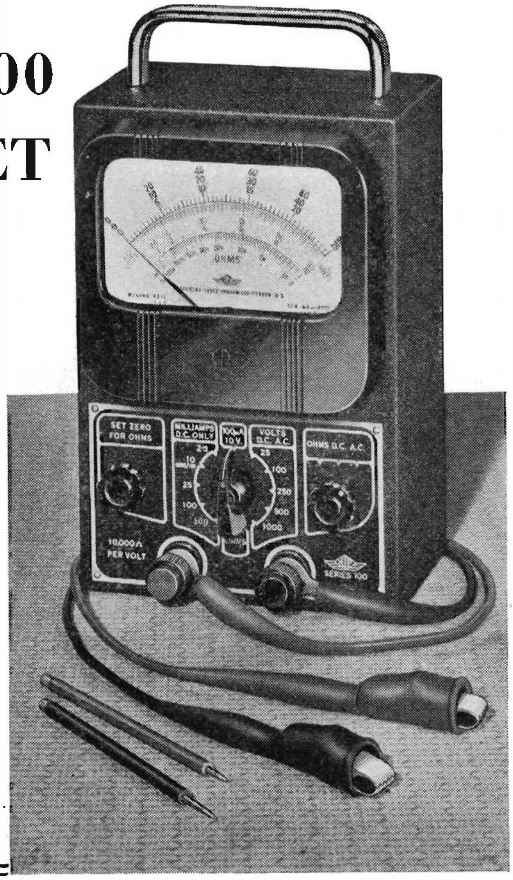
SOMERFORD CHRISTCHURCH HANTS
Tel.: Christchurch 1025

TRANSFORMERS FOR THE RADIO, TELEVISION AND ELECTRONIC INDUSTRIES

GR

Used wherever Quality is called for

PULLIN SERIES 100
MULTI-RANGE TEST SET

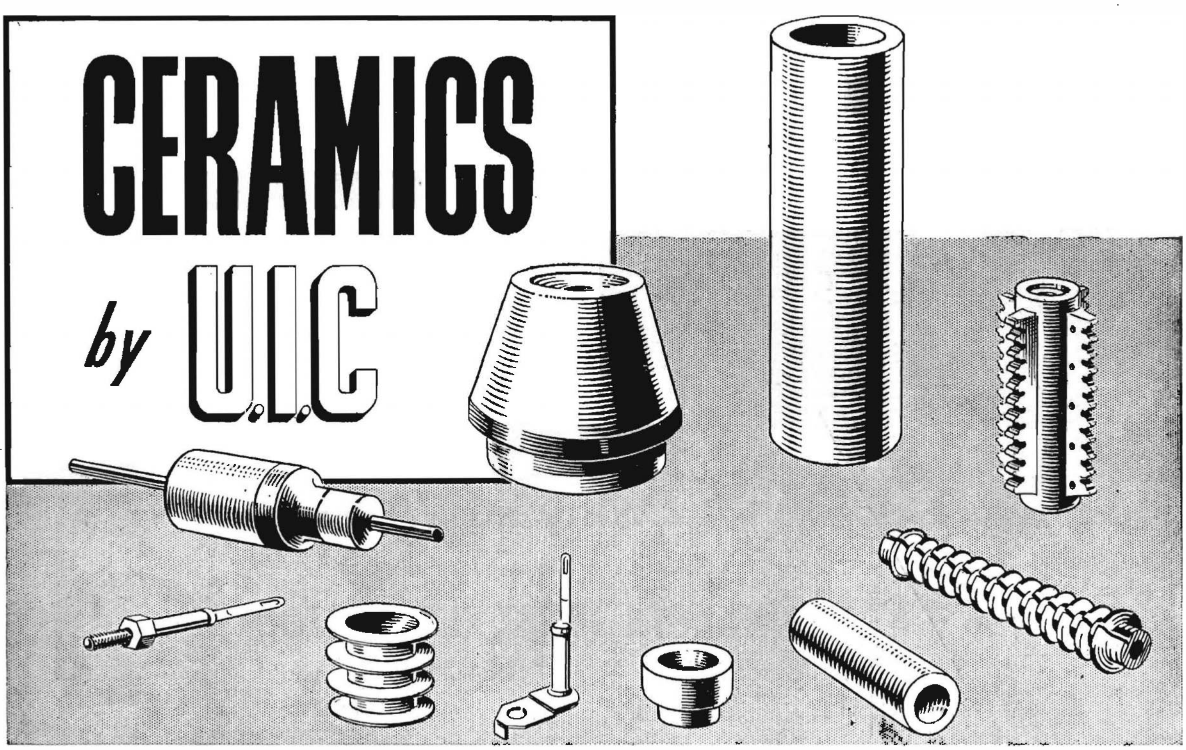


The universal testing set for Service Engineers. **Sensitivity—10,000 ohms per volt.** Strong metal case with carrying handle—complete with leads having detachable bulldog clips and test prods. Size 9 in. by $5\frac{1}{2}$ in. by 4 in.

RANGES

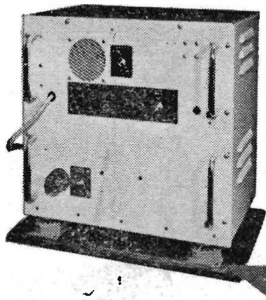
AC/DC Volts ; 10, 25, 100, 250, 500, 1,000.
D.C. Milliamps ; 2.5, 10, 25, 100, 500.
AC/DC Microamps ; 100 Microamps 10v. range.
Resistance ranges ; 0/1 Meg. (13,000 ohms mid-scale). 0/10,000 ohms (135 ohms mid-scale.)

MEASURING INSTRUMENTS (PULLIN) LTD.
ELECTRIN WORKS, WINCHESTER STREET, LONDON, W.3
Phone : ACORN 4651-3 & 4995



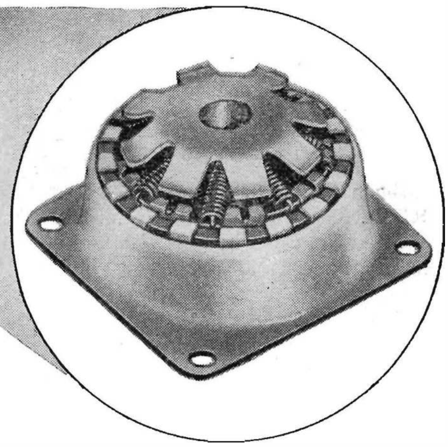
UNITED INSULATOR COMPANY LTD · TOLWORTH · SURBITON · SURREY · ENGLAND
Cables: Calanel, Surbiton
Telephone: Elmbridge 5241

ISOLATE that VIBRATION *through* EQUIFLEX



THE ALL-METAL SPRING MOUNTING

- EQUAL FLEXIBILITY IN ALL DIRECTIONS
- CAN BE LOADED IN ANY DIRECTION
- UNAFFECTED BY CLIMATIC CONDITIONS
- VARIOUS TYPES FROM 1-35 lbs PER UNIT
- VIBRATION IS BOTH DANGEROUS AND COSTLY



Write for Catalogue and Price List to

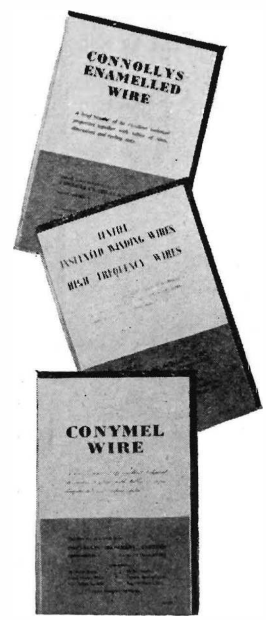
A.WELLS & CO. LTD.

STIRLING RD WALTHAMSTOW, LONDON E.17.

M.O.S. TYPE APPROVED. PATENT No 571026
FOREIGN PATENTS GRANTED

Backed by 50 years manufacturing experience Connollys range of winding wires are unsurpassed for quality. Whether the insulation consists of Enamel, Cotton, Silk or Rayon, strict technical control over every stage of manufacture—plus the priceless fund of experience—ensures uniformity of quality of the highest degree.

Send for free leaflets describing these products



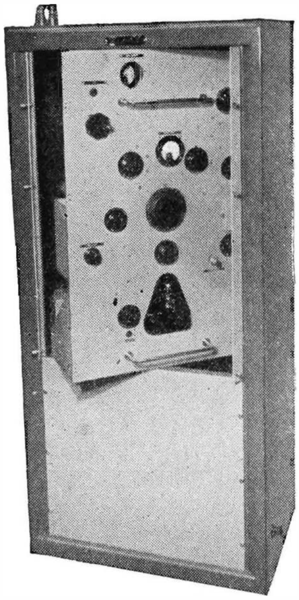
FOR ALL TYPES OF WINDING WIRES

The largest manufacturer of fine enamelled wire in the world

CONNOLLYS (BLACKLEY) LTD.

MANCHESTER 9 **CHEetham Hill 1801**

London Office : 34 Norfolk Street, London, W.C.2 TEMple Bar 5506
Birmingham Office : 19 Bent Avenue, Quinton, Birmingham, 32. WOOdgate 2212



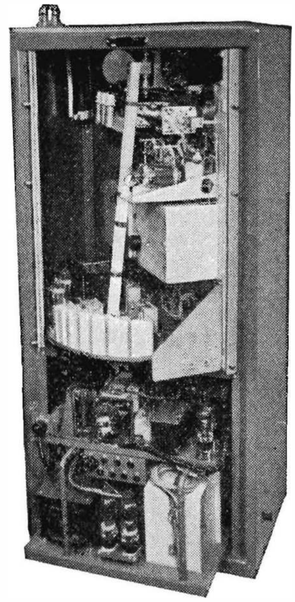
Chassis partly rotated.

The new Redifon G.77 is designed to meet the increasing need for an efficient, medium powered, general purpose H.F. transmitter. It has a power output of 150 watts over the wide frequency range of 1.5 to 24 M/cs and will feed into a wide variety of aerials. Both C.W. only and C.W./Telephony versions are available.

An outstanding feature is the rotating front panel which pivots vertically through 360 degrees to expose the H.F. and modulator units for rapid and easy maintenance.

COMMUNICATIONS

Redifon Radio



Chassis rotated and power units partly withdrawn.

Radio Communications Division

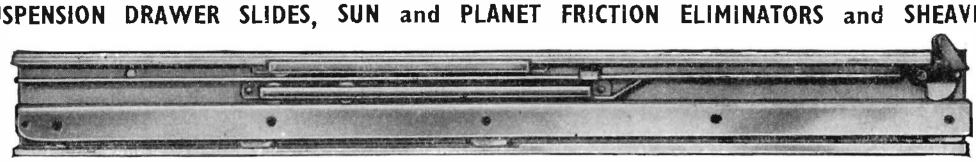
REDIFON LIMITED, BROOMHILL ROAD, WANDSWORTH, S.W.18

DESIGNERS & MANUFACTURERS OF RADIO COMMUNICATION & INDUSTRIAL ELECTRONIC EQUIPMENT Phone: VANdyke 7281

ALWAYS "FIT"

AUTOSET

SUSPENSION DRAWER SLIDES, SUN and PLANET FRICTION ELIMINATORS and SHEAVES.



Type A Slides as above supplied in 15⅝″, 17⅝″, 21″, 23⅝″, 25¼″ and 27¼″ lengths. Heavy type A Slides supplied in lengths 23⅝″, 28¼″, 32″ and 37″. Type A series case strips may be drilled and countersunk or provided with ears or lugs.

Two arm Type B Slides supplied in 23⅝″ lengths down to 9″ lengths. 13 gauge Heavy Type B Slides in lengths up to 30″.

We also supply heavy duty castors up to 30 tons capacity each, including twin pneumatic wheeled types up to 40″ diameter.

OVER 6,000 TYPES AVAILABLE

Ask for Brochure.

Engineers, Patentees and Sole Manufacturers

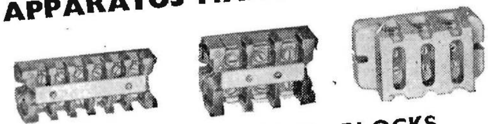
AUTOSET (PRODUCTION) LTD., Dept. O, Stour St., Birmingham 18.

Phone : EDG 1143/4. *Est.* over 30 years.

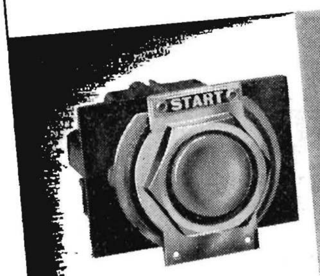
Please mention "Electronic Engineering."

AT 3

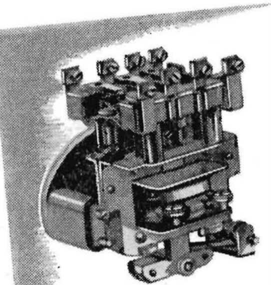
DONOVAN ACCESSORIES — FOR THE ELECTRONIC APPARATUS MANUFACTURER !



TYPE J.96 TERMINAL BLOCKS
Made in 15, 30 and 60 amp. sizes



Type C.30 **PUSH BUTTON UNIT** arranged for mounting on customers' own cover plate.



Type **A.11 A.C. POWER RELAY**,—4-pole with N.O or N.C. contacts.

THE DONOVAN ELECTRICAL CO. LTD.
Safuse Works · Stechford · Birmingham 9

ELECTRONICS

2nd Edition

By J. Millman, The City College of New York and S. Seely, Syracuse University.

598 *pages*, 9 × 6, 62*s*.

A thorough revision and modernization of this outstanding book, the second edition retains the basic philosophy of the original edition by presenting physical electronics and engineering electronics together. In addition the text contains many new line drawings, illustrative examples and problems.

Available from all booksellers

McGRAW-HILL
Publishing Co., Ltd.
Aldwych House, London, W.C.2.

"VARIAC"—

Regd. Trade Mark

Infinitely Variable

VOLTAGE REGULATING TRANSFORMER

Smooth Control

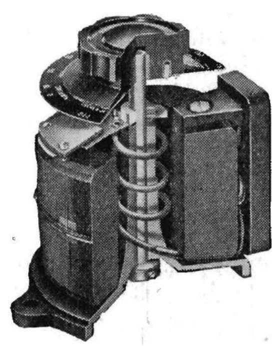
Linear scale, various markings.

115 or 230 volts service or others if required.

Special types for 500 cycle or 2,000 cycle, etc., can be supplied.

Low temperature rise.

Bench or panel type mounting reversible shaft.



Reasonable overload capacity.

Output independent of load.

Single or duplex voltage outputs. (Type 100 RM/2B).

Supplied with or without screen.

Ring-type laminated core.

The illustration shows Types 200 (580 and 860 va). Larger types are made-up to 7 Kva.

Write for Catalogue V549 for complete data

CLAUDE LYONS LTD.

ELECTRICAL & RADIO LABORATORY APPARATUS, ETC.

180 Tottenham Court Road, London, W.1, and
76 Oldhall Street, Liverpool 3, Lancs.

Dainite

A PERSONAL SERVICE IN

MOULDED RUBBER COMPONENTS

OUR TECHNICIANS ARE AT YOUR SERVICE

THE HARBORO' RUBBER CO. LTD.
MARKET HARBOROUGH. *Telephone : 2274/5*

BRADMATIC LTD.

Offer the BRADMASTER

Model 5 Tape Desk

- Built to professional standards.
- Two speeds—3¾ and 7½ inches per second.
- Fast wind and rewind—full reel rewound in 1½ minutes.
- Heavy alloy flywheel. Freedom from "wow" and "flutter."
- Double servo brakes on each hub.
- Push Button control.
- Three heavy duty motors.
- Three shielded Bradmatic heads.
- Plug box, providing shielding for head leads and eliminating hum and cross talk.
- Size : 13½ in. × 15¼in. × 6¾ in. deep.

PRICE : £41 . 0 . 0.

Hi-fidelity magnetic sound heads :	
type 5 R.P. (record/play head)	£3 5 0 each
type 5 E (erase head)	£3 5 0 „
Super fidelity magnetic sound head, type 6 R.P. (record/play lead)	£3 15 0 „
Composite screening cans (constructed of steel and mumetal)	4 6 „
Oscillator coils	8 0 „
Tape on 7 in. reels, 1,200 ft. :	
Emitape, type 65	£1 5 0 „
G.E.C. Grade "A"	£1 10 0 „
Durex type, MC I—III	£1 15 0 „

Amplifiers and Microphones supplied.

Trade Supplied. *Send for Lists to the Sole Manufacturers :*

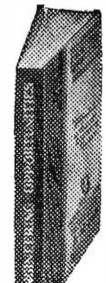
BRADMATIC LIMITED
STATION ROAD • ASTON • BIRMINGHAM 6
Phone : EAST 0574. *Grams : Bradmatic, Birmingham.*

WILKINSON'S OF CROYDON

SIGNAL AND NOISE GENERATOR. This Test Set Type 210 has a range of 20-88 Mc/s in 4 Bands. Output 10 M/V. approx. Modulated or unmodulated. Noise generator output 5 Microvolts with attenuator, Crystal controlled, 2 Crystals, Vernier adjustment. Brand new. Input 80 and 115 volts 1,000 cycles, £20, or 230 volts 50 cycles, £25.
ELECTRONIC TEST METER Model 664 measures 1/10 ohm to 1000 megohms in 6 ranges, also AC/DC volts up to 1000, etc. Complete with instruction book, £27 10s.
TEST SET 205. Wavemeter range. 3.05 to 3.35 centimeters, built-in oscillator with 9 valves including Klystron type CV.129, etc., in good condition, £20.
MICROAMMETER 0-50 2½ Flush Type, contained in Test Set 28. A very sensitive meter. Only 50s. each, complete.
PHOTOMULTIPLIER WITH NETWORK No. 931A. Contained in Transmitting Unit APQ9. £5 each. Carriage and packing, 10s.
BLASTING GALVANOMETER. Scale 0-25. Westinghouse. With leather case. New and boxed. 55s. each.

19, LANSDOWNE ROAD, CROYDON
CRO : 0839.

AMBITIOUS ENGINEERS

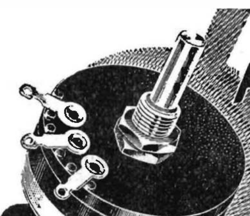


HAVE YOU HAD *YOUR* COPY OF "ENGINEERING OPPORTUNITIES"?

Whatever your age or experience—you must read this highly informative guide to the best paid engineering posts. The handbook contains particulars of **A.M.I.C.E., A.M.I.Mech.E., A.M.I.M.I., A.M.Brit.I.R.E.,** and other important Engineering Examinations, and outlines home-study courses in all branches of **Civil, Mechanical, Electrical, Automobile, Radio and Aeronautical Engineering, Government Employment, Draughtsmanship, Building and Plastics, Matriculation.** etc. We Guarantee *"NO PASS—NO FEE"*
If you are earning less than £12 a week you cannot afford to miss reading "**Engineering Opportunities.**" It tells you everything you want to know to secure your future. Write for this enlightening guide to well paid posts **NOW—FREE** and without obligation.

BRITISH INSTITUTE OF ENGINEERING TECHNOLOGY **BIET**
337a Shakespeare Hse., 17/18 Stratford Place, London W1

POTENTIOMETERS



Wire-wound and Composition types. Single, Ganged, Tandem Units. Characteristics : linear, log., semi-log., non-inductive. etc. Full details on request.

RELIANCE

RELIANCE MNFG., CO. (SOUTHWARK), LTD.,
SUTHERLAND ROAD, HIGHAM HILL, WALTHAMSTOW, E.17.
Telephone : Larkswood 3245

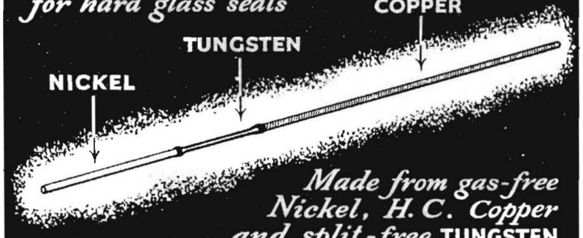
"J.B." SERVICE (BEXLEYHEATH) LTD.

5 MAYPLACE ROAD WEST, BEXLEYHEATH, KENT

OFFER

SIGNAL GENERATOR I-96-A. FOR USE WITH S.C.R. 522. £50.
DYNAMOTOR UNIT PE-94-A. FOR USE WITH S.C.R.522. £12.
R.F. WATTMETER. TS-87/AP.
RANGE O-30 WATTS. £25.
DUPLEXING UNIT. CTZ. 50 ACW.
(DOUBLE TROMBONE) FOR TYPE BL AND BN SERIES. £5.
TRANSFORMER. 1 KVA. 230V, 115V. £4 10s.

Three piece lead wires — for hard glass seals

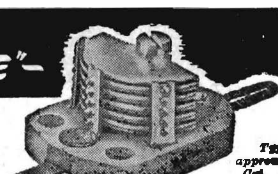


Made from gas-free Nickel, H. C. Copper and split-free **TUNGSTEN**

ELECTRO-ALLOYS LTD 12 Brunel Rd. London, W.3
Makers of TUNGSTEN and MOLYBDENUM Products

"TECHNICAL EXCELLENCE"—

—combines with beauty and soundness of DESIGN in the



Type approved Cat. A No. 464.

OXLEY

[*AIR DIELECTRIC TRIMMER*]

Width: 16.5 m/m. Length: 22 m/m. Height: 1.5 to 8pF—7.5 m/m. 1.8 to 20pF—10 m/m. 2 to 26pF—11 m/m. 2 to 32pF—12m/m. Law: Straight line capacity. Power Factor: Less than .001. Insulation: Over 2,000 megohms. Voltage: 500 D.C.

OXLEY DEVELOPMENTS CO. LTD.
ULVERSTON, NORTH LANCS. · TEL.: ULVERSTON 3306

INDEX TO ADVERTISERS

Printed in Great Britain by The Press at Coombelands, Ltd., Addlestone, Surrey, for the Proprietors, Morgan Brothers (Publishers) Ltd., 28, Essex Street Strand, W.C.2. Registered for Transmission by Canadian Magazine Post

No. 1 Laboratory Instruments

The experience gained from over 60 years in the design and manufacture of precision instruments is embodied in Weston Laboratory Standards. Endless care in the selection and ageing of materials and in the assembly and calibration of the instruments ensures the maintenance of the extremely high accuracy of 0·1%. Features include 12" Vernier Scale, magnetic shielding and self-contained thermometer. Full details of these instruments and of the full Weston range of switchboard, panel, first grade and sub-standard instruments are available on request.

WESTON
Electrical Measuring Instruments

SANGAMO WESTON LIMITED

Enfield, Middlesex. *Telephone : Enfield 3434 (6 lines) and 1242 (4 lines). Telegrams : Sanwest, Enfield.*

Branches : Glasgow · Manchester · Newcastle-on-Tyne · Leeds · Liverpool · Wolverhampton · Nottingham · Bristol · Southampton · Brighton