Electronic Engineering

JANUARY 1953

TWO SHILLINGS

CLASSIFIED ANNOUNCEMENTS

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

OFFICIAL APPOINTMENTS

AIR MINISTRY requires Scientific Officers for Operational Research on wide variety of problems, in London and provinces, under direction of Scientific Adviser to Air Ministry. Qualifications: First or Second Class Honours Degree or equivalent in physics, engineering or mathematics. Salary: (London) within range £440-£707 (men): £440-£576 (women). Provincial rates somewhat lower. Posts unestablished, with possibilities of establishment for successful candidates whilst remaining under age 31. Application forms, quoting A.285/52/A, from M.O.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1. Closing date 24th January, 1953. W 2140

ASSISTANTS (SCIENTIFIC) required by Government Department in Eastcote. Applications are invited from men and women between the ages of 16 and 25, possessing the equivalent of the General Certificate of Education or who are competent of reaching this standard within two years. A pass in Maths or Science an advantage. Older candidates may be considered exceptionally on grounds of experience in an industrial or technical branch of the Services. The work will be concerned with Physics and Electronics applying to communications. Immediate appointments will be to unestablished rank but opportunities to compete for established appointments will be given later. Salary (Intermediate): Men, £198 (Age 16) to £379 (Age 28). Women, £198 (Age 16) to £340 (Age 28). Write: Establishment Officer (B.19A1), Government Communications Headquarters, Lime Grove, Eastcote, Ruislip. W 2117

CROWN AGENTS FOR THE COLONIES. Assistant Signals Officer required by the Government of Nigeria for the Aviation Department for one tour of 18 to 24 months in the first instance. Commencing salary (including allowances) according to qualifications and experience either (a) in scale £750 rising to £1,315 a year, with the prospect of permanency or (b) in scale £807 rising to £1,453 a year, on a temporary basis with gratuity of £25 for each period of three months' satisfactory service. Outfit allowance £60. Free passages for officer and wife, and assistance towards cost of children's passages, or their maintenance in the United Kingdom. Liberal leave on full salary. Candidates must be Associate Members of the Institute of British Radio Engineers, or possess City and Guilds certificates in radio communication, or technical electricity, or a satisfactory pass in the Ministry of Civil Aviation Radio Mechanics' course. Apply at once by letter, stating age, full names in block letters, and full particulars of qualifications and experience, and mentioning this paper to the Crown Agents for the Colonies, 4, Millbank, London, S.W.1, quoting on letter M.29637.G. The Crown Agents cannot undertake to acknowledge all applications and will communicate only with applicants selected for further consideration. W 2127

ELECTRONICS TECHNICIAN required to undertake practical work of construction and maintenance of E.E.G. and other electro-medical equipment. Applicant should have a good working knowledge of electronic theory and practice. Practical experience in hospital workshop or industry essential. Salary scale £495-£580. Apply giving full particulars, age, experience, etc., to The Physician Superintendent, Crichton Royal Hospital, Dumfries. W 1621

KINGSTON - UPON - HULL EDUCATION AUTHORITY. Municipal Technical College. Principal: Emlyn Jones, M.Sc., F.R.I.C. Required to commence duty in April, 1953, Teacher (Assistant Grade B) for Radar and Electronic Engineering. Applicants must possess the Ministry of Transport Radar Maintenance Certificate or an equivalent qualification. Considerable practical experience in marine radar engineering is essential and applicants should preferably have had teaching experience. The person appointed will be required to conduct correspondence courses as part of the normal teaching duties. Salary: £490 × £25—£765 per annum, plus additions for training and/or graduate qualifications. Further particulars and application forms, to be returned within fourteen days of the date of this issue, will be supplied by the Chief Education Officer, Guildhall, Kingston-upon-Hull, on receipt of stamped, addressed, foolscap envelope. W 2124

MINISTRY OF SUPPLY require Electrical Engineer for Experimental Establishment at Felixstowe, Suffolk. Experience in maintenance and design of aircraft electrical systems or in light electrical engineering or telecommunications engineering is required. Workshop experience desirable. Qualifications: Higher School Certificate (Science) or equivalent but other qualifications such as H.N.C. or Degree in Electrical Engineering may be an advantage. Salary within range Experimental Officer (minimum age 26 years), £597-£754, Assistant Experimental Officer, £264 (age 18)-£555. Women somewhat less. Post unestablished. Application forms from M.O.L.N.S., Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1, quoting D 466/52A. Closing date 16th January, 1953. W 2134

MINISTRY OF SUPPLY, R.A.E., Farnborough, requires Scientific Officer in Radio Division for investigations in the field of radio frequency measurement especially at V.H.F. and centrimetric frequencies. Qualifications: 1st or 2nd class Honours Degree in physics with mathematics, or equivalent, and a leaning towards experimental rather than theoretical work. Salary within range £417-£675. Women somewhat less. Post unestablished. F.S.S.U. benefits may be available. Application forms from M.O.L.N.S., Technical and Scientific Register (K), 26, King Street, London, S.W.1, quoting A314/52/A. Closing date 12th January, 1953. W 2141

MINISTRY OF SUPPLY, R.A.E., Farnborough, requires Electrical Engineer or Physicist to undertake experimental work on design of fuses for bombs and guided weapons. Qualifications: Higher School Certificate (Science) or equivalent, but Degree or H.N.C. in Electrical Engineering or Physics may be an advantage. Experience of electronics required and some knowledge of centimetric technique desirable. Salary within ranges, Experimental Officer (min. age 26), £597-£754, Assistant E.O., £264 (age 18)-£555. Women somewhat less. Post unestablished. Application forms from M.O.L.N.S., Technical and Scientific Register (K), Almack House, 26, King Street, London, S.W.1, quoting D 474/52A. W 2153

PERSONNEL experienced in the maintenance and repair of Armament, Radar and Electronic Control Equipment are required for employment as Civilian Technical Assistants in the South and South West Counties. The standard required is that of Armament Artificer REME. Salary range £480 to £598 according to age and length of service. Opportunities exist for promotion to higher grades with salaries up to £891. A number of civilian instructors with similar experience are required for service with the Territorial Army. Replies giving full details of age, experience, technical qualifications and service ranks held (if any) should be sent to: ADME, HQ 2 AA Group, Barossa Barracks, Stanhope Lines, Aldershot, Hants. W 2156

PROFESSIONAL ENGINEERS in various Government Departments. The Civil Service Commissioners invite applications for about 150 pensionable posts in a wide variety of engineering duties. Applications may be accepted up to 30th September, 1953, but an earlier closing date may be announced. Candidates must be under 35 on 1st January, 1953, with extension for regular service in H.M. Forces and up to two years for permanent civil service. For the Post Office they must be at least 21, for the Ministry of Supply and Ministry of Civil Aviation at least 23, and for all other Departments at least 25 on that date. Generally a candidate must possess a University Degree in Engineering or be a Corporate Member of one of the professional institutions —Mechanical Engineers, Electrical Engineers, or Civil Engineers or have passes in, or exemption from, Sections A and B of the corresponding Associate Membership examinations. Exceptional candidates of high professional attainment, but without the specified qualifications, may be admitted. For some posts Associate Fellowship of the Royal Aeronautical Society or an Honours Degree in Physics will be accepted. Inclusive salary scale (men in London) £628 (at age 25) to £970. Starting salary according to age up to £875 at 34. Candidates entering below age 25 will start at salaries varying from £429 at age 21 to £549 at age 24. Prospects of promotion. Salaries of next higher grades are £970-£1280 and £1331-£1536. Somewhat lower for women and in the provinces. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S85/53. W 2160

UNIVERSITY OF EDINBURGH. Applications are invited for I.C.I. Research Fellowships in Biochemistry, Chemistry, Engineering, Pharmacology or Physics, to which some appointments will date from 1st October, 1953 (or earlier in the case of selected candidates who may be available before that date). The salary will depend upon qualifications and experience but will be within the range £600 to £900 per annum, together with F.S.S.U. benefits and family allowances. Forms of application and further particulars may be obtained from the undersigned. Applications (two copies) should be submitted not later than 23rd February, 1953. Charles H. Stewart, Secretary to the University. W 2090

SITUATIONS VACANT

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

AIRTECH LIMITED, Aylesbury & Thame Airport, Haddenham, Bucks, require Radio Testers capable of working on own initiative to Ministry specifications. Small batch production. Varied and interesting work covering Audio to U.H.F. Preference given to applicants with experience on Aircraft Radar Installations. Write giving age, details of experience and qualifications. W 1630

A LARGE and well established engineering company opening a Drawing Office in the Central London area require Press Tool Designers and Draughtsmen. Applicants should have had tool room apprenticeship or equivalent, followed by experience on first class press tool work in the light electrical and mechanical field. Applications are invited from men of sufficient experience and ability to justify very good salaries. Excellent working conditions and staff pension scheme in operation. Please write, in confidence, giving details of experience and quoting reference N.94 to Box No. W 2122.

A NUMBER OF VACANCIES exist in the Research Laboratories of Ericsson Telephones Ltd., Beeston, Nottingham, for work on several interesting and important projects employing electronic switching pulse techniques and electronic instrumentation. A good Degree in physics or electrical engineering is required for some vacancies, for others Higher National or its equivalent. Experience in some field of electronics is necessary for all but the more junior vacancies. Starting salaries for suitable applicants will be up to £750 p.a. Applicants must be of British nationality and should address applications to the Personnel Officer. W 2990

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

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

COILWINDING—Electronic Equipment. Engineers required for the undermentioned appointments by a large and expanding engineering company. 1. Time Study Engineers. 2. Estimating Engineers. 3. Planning Engineers. 4. Design Engineers (Transformers). 5. Senior and Junior Design Draughtsmen. 6. Setters—Leesona Coilwinding Machines. Excellent prospects—Pleasant working conditions—Good salaries. Please write, giving details of experience and quoting reference N.47, to Box No. W 2105.

DECCA RADAR LTD. invites applications from microwave, electronic and mechanical engineers to join the Company in its extensive work in a wide field of microwave link and radar development. The Company offers excellent starting salaries and first rate opportunities for men to exploit their initiative and to rise rapidly to responsible posts. Graduates without industrial experience who are prepared to undertake intensive training are also invited to apply Director, Radar Laboratory, 2, Tolworth Rise. Surbiton, Surrey. W 150

DESIGN AND DEVELOPMENT ENGINEERS are required by the English Electric Co. at their Stafford and London offices for work on mercury arc rectifiers. Scope for originality of work in a widely varied range of technical interests. Previous rectifier experience advantageous but not essential. Applicants should have had a sound basic training to Degree standard in electrical engineering and possess above average mathematical ability. Please reply quoting Ref. 1064 to Central Personnel Services, English Electric Co. Ltd., 336/7, Strand, London, W.C.2. W 2174

DESIGNER/DRAUGHTSMAN with H.N.C. is required by the Research Laboratories of The General Electric Co. Ltd., North Wembley, Middlesex, for work on the mechanical design of centimetre wave transmitting valves and associated apparatus. Some previous experience is desirable. Apply to the Staff Manager (Ref. RLO/179) stating age, qualifications and experience. W 2116

DEVELOPMENT ENGINEER required by progressive and expanding scientific instrument firm, for laboratory work on design of new electronic and electrical instruments. Applicants should have a Degree or equivalent in physics or electrical engineering. Previous experience is desirable, but recently qualified men will also be considered. Write with full details to W. G. Pye & Co. Ltd., "Granta" Works, Newmarket Road, Cambridge. W 1625

DEVELOPMENT ENGINEER aged 25/30 with HNC. or Degree. Experienced in design of laboratory instruments, e.g., R.C. oscillators, bridges, feed-back amplifiers, recorders. For old established firm in S.E. London. Applications giving full particulars and salary required to Box No. W 2125.

DEVELOPMENT ENGINEERS are required by the Electronics Division of Murphy Radio Limited to work with a subsidiary Company at Ruislip, Middlesex. The work may be in the general field of Electronics but special projects require Personnel to work on ground and airborne aerial systems and telemetry. Applicants should write in the first instance quoting "Engineers Ruislip" giving full particulars of their experience and qualifications to Personnel Department, Murphy Radio Limited, Welwyn Garden City, Herts. W 2152

DEVELOPMENT ENGINEERS, Senior and Junior, for Radio, Television and Electronics, North London area. Previous experience of circuit development work essential. Details of qualifications, experience and salary required c/o Newspaper to Box No. W 2136.

D. NAPIER & SON LTD., Luton Airport, Beds, have a vacancy for an Instrument Engineer, H.N.C. or equivalent, practical workshop and test room background, required as chief assistant on instrumentation for aircraft engine flight development and allied projects. Measurement and recording of temperature, pressure, flow, etc., is involved and experience of allied electronics in this field essential. All applicants apply to the above address as soon as possible. W 2066

D. NAPIER & SON LTD., Luton Airport, Beds, have a vacancy for a Junior Electronic Laboratory Assistant, familiar with C.R.O. practice, for experimental work in connexion with engine development and allied projects. All applicants apply to the above address as soon as possible. W 2067

ELECTRICAL INSPECTOR. A large firm of Engineers (Mechanical), Birmingham, have a vacancy on their Staff for an Inspector aged 25 to 35, with electronic and electrical experience. Post offers good prospects to man familiar with A.I.D. and Admiralty Standards, and preferably with some mechanical experience. 5-day week of 44 hours. Staff Pension Scheme. Apply, giving full details of experience, age and salary required to Box No. W 2130.

ELECTRO-MECHANICAL ENGINEERS required with good academic qualifications, apprenticeship, theoretical background and knowledge of production methods 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 Co. Ltd., Great West Road, Brentford, Middlesex. W 2071

ELECTRONIC ENGINEER required to take charge of production testing of electronic instruments. Experience rather than qualifications required. Write with full details to W. G. Pye & Co. Ltd., "Granta" Works, Newmarket Road, Cambridge. W 1626

ELECTRONIC ENGINEER required by manufacturer North West London. Practical knowledge of Television and Pulse Circuitry essential. Write stating age, experience and salary required to Box No. W 2126.

ELECTRONIC ENGINEERS required for Research Laboratory, Associated Electrical Industries Limited, Aldermaston Court, Aldermaston, Berks. Successful applicants will develop specialized electronic equipment of all kinds, in collaboration with physicists, for fundamental research projects. Send full details of qualifications and experience to The Personnel Officer. W 154

ELECTRONIC ENGINEERS and Electronic Design Engineers required for work on flight simulators. Applicants should write, stating experience and qualifications to the Personnel Officer, Air Trainers Limited, Bicester Road, Aylesbury, Bucks. W 2155

ELECTRONIC ENGINEERS. (a) Section Leaders and (b) Assistant Engineers required for working on special experimental field trials of guided weapons. Section Leaders should have at least H.N.C. and 5 years' experience in the development of electronic devices in the microwave, pulse or communication field, and be capable of taking responsibility for the serviceability of weapons for trials and of undertaking parallel development work in the laboratory. Assistant Engineers having a similar background, or considerable experience of small prototype electro-mechanical instruments, are required to work under the Section Leaders. Applicants may have the opportunity of carrying out some of the work in Australia at a later date. Good salaries. Subsistence allowances while working away from base. Pension scheme. Details should be sent to the Assistant Manager (A), The Fairey Aviation Co. Ltd., Dept. E, Research and Armament Development Division, Heston Aerodrome, Hounslow, Middlesex. W 2158

ELECTRONIC ENGINEERS are required for development work on aircraft instruments. They should possess a Degree in Electrical Engineering or Physics or Higher National Certificate or similar qualifications. Previous laboratory experience in physics, electrical engineering or instrument technology would be an advantage. Guildford area. Send details of qualifications and experience, quoting Ref. E.10, to Box No. W 1610.

ELECTRONIC ENGINEER required by well-known North London Company. Wide knowledge of low frequency circuit techniques with sound design ability. The laboratory specializes in industrial and medical electronic apparatus for small scale production. Degree, corporate membership of I.E.E. or equivalent required, interesting work with good opportunities, pension scheme, etc. Write stating qualification, age and experience to Box No. W 2172.

ELECTRONICS. An exceptional opportunity is offered to a young electronic engineer possessing ability and ambition to act in a managerial capacity as head of a rapidly growing department engaged in new developments in this field. Commencing salary up to £1250 per annum, according to qualifications and experience. Prospects dependent upon initiative and personal efforts in building up successful business. Staff pension scheme in operation. Applications, which must state full particulars of qualifications and previous experience, will be treated in strict confidence. Box No. W 2171.

ENGINEER required to undertake the development of low frequency iron cored components. Previous experience desirable. Salary according to qualifications and experience. Apply in writing to Advance Components Limited, Back Road, Shernhall Street, E.17. W 1608

ENGINEER required to develop electrical transducers for the measurement of pressure and vibration. Applicants must have a University Degree and previous experience in design of small electro-mechanical systems would be an advantage. Responsibilities will include initiation of development programmes, discussion of users' requirements and the handling of commercial correspondence. Apply Southern Instruments Ltd., Fernhill, Camberley, Surrey. W 1619

ENGINEER required for theoretical and experimental work on Aircraft Fuel Contents Gauging. Qualifications—Electrical Engineering or Physics Degree or equivalent. Experience of measurements problems advantageous. South-West of London. Send tabulated details of experience, quoting Ref. E9, to Box No. W 1611.

ENGINEERS required for responsible trials work on Guided Weapons. Good general scientific education up to Degree standard, and enthusiasm for this interesting but often arduous work essential. Vacancies in Middlesex, Warwickshire and West Wales. A fair amount of travel may be involved. Preference given to candidates who have previously held responsibility for test and repair of electro-mechanical and electronic devices. Applications in writing to Personnel Manager, Sperry Gyroscope Co. Ltd., Gt. West Road, Brentford, Middlesex. W 2121

ENGINEER MANAGER required with experience in the layout of new Works for production of batch and mass produced articles connected with electrical industry. Applicants should have had similar experience, where modern methods have been employed for machining and assembly and able to produce satisfactory results essential. Only those capable of commanding a substantial salary need apply for the post which is permanent and pensionable. Full details of experience and age should be sent in confidence to Box No. W 1614.

EXPERIENCED Radio Testers and Inspectors required for production of communication and radio apparatus. Also Instrument makers, wirers and assemblers for Factory Test apparatus. Apply Personnel Manager, E. K. Cole Ltd., Ekco Works, Malmesbury, Wilts. W 146

EXPERIENCED TECHNICAL WRITER required to produce maintenance handbooks on electronic computing equipment. Apply in writing, stating salary required, to Mr. G. B. Ringham, Flight Simulator Division, Redifon Ltd., 59, Webber Street, London, S.E.1. W 2138

FERRANTI LTD. have immediate vacancies for men with Electrical Engineering qualifications to undertake the advanced testing of naval anti-aircraft Fire Control Equipment involving electronics and servo mechanisms either in firms' workshops or on board H.M. Ships in home ports. Salary in accordance with age and experience between £356 and £650 per annum. Normal expenses plus a generous allowance are paid when working out. Previous experience of this type of work, though desirable, is not essential. Forms of application from Mr. R. J. Hebbert, Staff Manager, Ferranti Ltd., Hollinwood. Lancs. Please quote reference HGN/X. W 2073

FERRANTI LTD., Edinburgh—invite applications from suitably qualified persons for the position of Research Engineer in their Small Transformer Department in Edinburgh. The duties involve investigations into new techniques and materials associated with transformers for use in electronic equipment with a view to their ultimate use in large-scale production. Candidates should preferably have a University Degree and experience in (1) Transformer design and development tendencies and/or (2) Electronic component research. Staff Pension Scheme and excellent conditions and equipment. Reply quoting Ref. T/RE and give full details of age, qualifications and experience to the Personnel Officer, Ferranti Ltd., Ferry Road, Edinburgh. W 2941

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

FERRANTI LTD., Moston Works, Manchester, have a vacancy for a Senior Valve Engineer in their Radio Valve Research Laboratory in connexion with the development of V.H.F. and microwave amplifier valves. Applicants should have a good Degree in physics or engineering with experience in V.H.F. valve development. The salary range is £800 to £1200 per annum and the Company has a Staff Pension Scheme. Application forms may be obtained from Mr. R. J. Hebbert, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote reference VG. W 2165

INSTITUTE OF LARYNGOLOGY AND OTOLOGY, 330/332, Gray's Inn Road, London, W.C.1. Laboratory Technician required for work mainly concerned with acoustics and hearing. Applicants should be between 20 and 30 years of age, should hold National or Higher National Certificates in Communication or Electrical Engineering or have had equivalent experience. Initiative and adaptability are more essential than previous experience of audio-frequency work. Salary according to qualifications and experience, with superannuation. Apply in writing to the Secretary giving details of qualifications and experience and the names of two referees. W 2146

INSTRUMENT CALIBRATORS AND TESTERS required for pyrometers and electronic control devices. Applicants must have previous experience or be of National Certificate standard in electrical knowledge. Apply Electroflo Meters Co., Ltd., Abbey Road, Park Royal, N.W.10. W 2150

JUNIOR ENGINEERS for calibration and maintenance of high grade A.F. equipment. Apply, giving age, full details of previous experience and technical qualifications, with salary required, to E.M.I. Studios Ltd., 3, Abbey Road, London, N.W.8. W 1629

JUNIOR RESEARCH ENGINEERS required for work in electronics field. Starting salaries up to £600. Applications to Personnel Officer, Ericsson Telephones Limited, Beeston, Nottingham. W 2149

LABORATORY TECHNICIAN required for the Electrical Engineering Department for work in the electronics field. Commencing salary according to experience, in the scale £338—£13—£442 plus London Weighting (max. £30). The successful applicant must join the contributory pension scheme. Application, giving age and full details of experience, to the Secretary, King's College, Strand, W.C.2. W 2139

M.R.G. LTD. have vacancies for Development Engineers for design work on Radio and Television. The openings cover a wide field from basic technical research to construction of experimental receivers, and models. Superannuation Scheme, etc., for suitable applicants. Application must be by letter in the first instance, giving all relevant details. to Mains Radio Gramophones Limited, 359, Manchester Road, Bradford. W 1617

MCMICHAEL RADIO LTD. require senior and junior engineers in their equipment division laboratory at Slough. Training and experience in the field of Applied Electronics (including Communications) and experience of working with Government Departments are the chief qualifications required. Write stating age and full details of training, qualifications and experience to the Chief Engineer, Equipment Division, McMichael Radio Ltd., Slough, Bucks. W 1578

MCMICHAEL RADIO LTD. require Senior and Junior Engineers in their equipment division laboratory at Slough. Training and experience in the field of applied electronics (including communications) and experience of working with Government Departments are the chief qualifications required. Write stating age and full details of training, qualifications and experience to the Chief Engineer, Equipment Division, McMichael Radio Ltd., Slough, Bucks. W 157

MUIRHEAD & CO. LTD., Precision Electrical Instrument Makers, Elmers End, Beckenham, require a Technical Writer to assist in the preparation of operating instructions and technical literature dealing with precision electrical measuring instruments, picture telegraph apparatus and remote control equipment. Qualifications: Degree or H.N.C.; some design experience; aptitude for this specialized form of writing. Apply with full particulars to Personnel Manager. W 2154

MURPHY RADIO LTD. have vacancies for experienced testers and inspectors for work on radio and electronic equipment with a subsidiary company at Ruislip, Middlesex. A number of qualified project supervisors are also required. Applicants should write in first instance giving full particulars of their experience and qualifications to Personnel Dept., Murphy Radio, Ltd., Welwyn Garden City, Herts. W 2101

MURPHY RADIO have vacancies in their Electronics Division for a first class Senior Design Draughtsman and a Senior Mechanical Designer. Applicants should be up to at least National Certificate Standard and have had experience in design of Electronic Equipment, small mechanisms or similar work and must be capable of working on their own initiative. Employment is permanent and pensionable and offers excellent opportunity of broadening experience in this interesting field of work. Full details of experience and qualifications should be included in applications which may be forwarded in confidence to Personnel Manager, Murphy Radio Limited, Welwyn Garden City. W 2050

OLD - ESTABLISHED METALLURGICAL COMPANY seeks technical liaison officer. Must have good general background with particular reference to Soldering techniques. Minimum age 35. Write in the first instance giving full particulars of experience, etc., and salary required to Box No. W 2133.

PROJECT ENGINEER required to be responsible for a laboratory engaged on development of Aircraft Fuel Contents Gauges and Associated Equipment. Applicants should possess qualifications in Electrical Engineering and/or Physics, and have had design and laboratory experience in the application of electronic techniques to airborne equipment. Apply in writing, quoting Ref. E8 and giving details of qualifications and experience, to the Chief Development Engineer, Waymouth Gauges & Instruments Ltd., Station Road, Godalming, Surrey. W 1609

PYE TELECOMMUNICATIONS LTD., Ditton Works, Cambridge, will shortly have vacancies for senior and junior engineers. Experience in V.H.F. design and engineering is essential. Vacancies also exist for engineers with specialist experience in multi-channel V.H.F. Telephony. Salary according to qualifications and experience. Please apply, stating age, qualifications and experience to the Personnel Manager. W 156

RECTIFIER TEST ENGINEERS required by the English Electric Co. Ltd., Stafford. Applicants must have previous experience of this type of work. Consideration will be given to men with O.N.C., although H.N.C. is preferred. Apply stating age and experience to Central Personnel Services, The English Electric Co., Ltd., 336/7, Strand, London, W.C.2, quoting reference 1031A. W 2114

RESEARCH ASSISTANTS required for the development of magnetic amplifier and electronic control systems. Experience in magnetic amplifier design is desirable. Laboratory in central London area. Write, giving full particulars of age, qualifications and experience, to Box No. W 2157.

RESEARCH ENGINEER required who has had a few years' experience in Radio, preferably with pulse techniques. Minimum starting salary of £600. Candidates should preferably have good Honours Degree in Physics or Engineering. Address applications to Personnel Officer, Ericsson Telephones Limited, Beeston, Nottingham. W 2147

SALES ENGINEER, electronic equipment, required by London group of small companies. Exceptional opportunity for young engineer with some selling experience. Send full details, date of birth, and indication of salary required, to Box No. W 2137.

SENIOR Radio Designer required. An interesting and responsible job with excellent future prospects is waiting for an engineer with several years' experience in development of Home and Export radio receivers. Applications may be addressed in confidence to the Personnel Manager, Murphy Radio Ltd., Welwyn Garden City, Herts. W 2106

SENIOR DRAUGHTSMEN required for checking in a large engineering company situated in the East London area. Applicants should have had previous experience of electronic equipment. Good salaries and staff conditions. Pension scheme in operation. Please write, quoting reference EE/SD, giving details of experience to Box No. W 2161.

SENIOR METHODS ENGINEER required to undertake the development of a new factory costing system in a medium size company in London engaged on batch production of mechanical and electrical meters. Apply stating age, training, experience and salary required to Box No. W 2151.

SENIOR TECHNICAL ASSISTANT required for process control and technical investigation into factory problems connected with the manufacture of cathode-ray tubes. Salary £550-£850 according to age and experience. Box No. W 2143.

SENIOR VALVE ENGINEER required by a well-known company. Previous experience of infra-red work is required. Salary commensurate with experience and qualifications. Please reply quoting reference AJEB to Box No. W 2142.

SOLDER TECHNICIAN. Old-established Company requires technical representative aged 21-35, must have metallurgical, radio and telecommunications background. Write in the first instance giving full particulars of experience, etc., and salary required to Box No. W 2132.

SOME GOOD OPENINGS available immediately and in the near future in a new Laboratory in Ottawa, Canada, for research and development work connected with an important civilian project. Experience in pulse circuitry switching devices and (or) computing systems preferred, although not essential. Positions available for Assistants with experience, and Engineers with one or more Degrees. Send summary to Box No. W 1624.

TECHNICAL ASSISTANTS required for development of electro-mechanical and electronic instruments (Marine). Work involves initial experiments, sea-going trials, pre-production models and factory liaison. Occasional visits overseas are arranged. Qualifications: Practical: 5 years' workshop or drawing office experience. Academic: City & Guilds Telecommunications Final Group Certificate, or equivalent. Apply Personnel Dept., Kelvin & Hughes Ltd., Barkingside, Essex. W 2120

TECHNICAL LIAISON OFFICER required. Applicants should have reached General Pass Degree standard, have completed National Service and been engaged in the Radio and Radar fields. Write giving details of experience to Personnel Officer, Ericsson Telephones Limited, Beeston, Nottingham. W 2148

TECHNICIANS between 20 and 30 years of age required for the initial and routine testing of relay wireless equipment including 1kW audio amplifiers. Applicants should have had some experience in the wire broadcasting, telephone or radio industries. Possession of C. & G. and/or National certificates an advantage. Commencing wage between £5 10s. and £9 per week according to qualifications, etc. 5½ day week, superannuation scheme and active sports and social club. Applications in writing to: Personnel Manager, British Relay Wireless Ltd., 343/5 Walworth Road, Southwark, S.E.17. W 2065

TEST ROOM ASSISTANT required, experience of audio frequency work, used to oscilloscopes and standard test room instruments, interesting prototypes. T. & R.P., 25, Bickerton Road, Upper Holloway, N.19. W 1627

THE GENERAL ELECTRIC CO. LTD., Brown's Lane, Coventry, require for work on Guided Weapons and like projects, Development Engineers, Senior Development Engineers, Mechanical and Electronic, for their Development Laboratories. Fields include Microwave

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SITUATIONS VACANT (Cont'd.)

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

and Pulse Applications. Salary range £400-£1250 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 2131

THE LABORATORIES of a leading firm of Communication Engineers in Southern England require the services of Senior Physicist to undertake development work on thermionic valves for centimetre wavelengths. The position offers the opportunity to work on a subject of considerable technical interest, with ample scope for ingenuity and enthusiasm. Applicants, who should possess suitable academic qualifications, will be required to show a good understanding of the principles of velocity modulation, and an appreciation of the operational requirements of microwave tubes. Importance is attached to experimental ability, and extensive experience with microwave measuring equipment is required. The salary offered will be commensurate with qualifications and ability. Applications should be addressed to the "Personnel Manager", c/o Box K.1641 A.K. Advtg., 212a, Shaftesbury Avenue, W.C.2. W 2064

THE PLESSEY COMPANY LIMITED has vacancies in its Telecommunications Engineering Department for Senior Engineers and Draughtsmen to work on long term private ventures and defence projects. Qualifications for Senior Engineers are a Degree in physics or engineering and at least two years' experience in electronic, radio or radar development work. Six or more years' experience of advanced work in the above field will be accepted as an alternative to a Degree. Qualifications for Draughtsmen are at least two years' Drawing Office experience on electronic, radio or electro-mechanical devices. The positions are permanent and pensionable and very good salaries are available for experienced men. Applicants should be of British birth and nationality. Apply, in confidence, to the Personnel Manager, The Plessey Company, Vicarage Lane, Ilford, quoting reference T.E.D. W 2123

THE STANMORE LABORATORIES of The General Electric Company, Limited, urgently require an experienced Senior Equipment Designer to co-ordinate the efforts of a team of Draughtsmen working with advanced research teams to prepare models of airborne radar equipment for flight trials. Candidates should have knowledge of M.O.S. design requirements and preferably have worked on similar projects over a number of years. Knowledge of waveguide components desirable but not essential. The selected candidate could expect a salary between £750 and £1000 per annum, depending upon age and experience. Apply in writing to the Staff Manager (Ref. SS/MW.3), The Grove, Stanmore Common, Stanmore, Middlesex, stating age, qualifications and experience. W 2128

TRANSFORMER DESIGNER required. An excellent opportunity exists for an engineer with thorough practical experience of radio mains transformer design and preferably some experience of R.F. coils and I.F. transformers. Applications may be addressed in confidence to the Personnel Manager, Murphy Radio Ltd., Welwyn Garden City, Herts. W 2107

TRANSFORMERS DESIGNER. A fully qualified Radio Engineer with a flair for Electronics and Associated Circuitry is required in Australia by this organization to take charge of a Laboratory dealing with the design and development of Transformers as used in the Radio, Electronics and Electrical Industries, Audio and Power Transformers, Power Chokes, etc. The applicant must have had considerable experience in one of the larger Radio Organizations, possess initiative, with ability to get things done and able to interview other Radio Engineers and advise on technical matters. Accommodation assured. This position is permanent and offers an excellent opportunity to the right applicant. All applications strictly confidential. Box No. W 1616.

TRANSFORMER ENGINEER is required to take charge of a group dealing with the design, construction and testing of a wide range of transformers and coils in a Research and Development Company. The range includes medium power, hermetically sealed, C type transformers, filter assemblies, and high-frequency coils and transformers. The applicant must possess the necessary technical knowledge and be able to lead a fair-sized team. The position is permanent and pensionable. A good salary will be paid, depending upon the qualifications and experience of the applicant. Working conditions are exceptionally pleasant in congenial surroundings; there is a good canteen on the premises, and there is an active Social and Sports Club. Five-day week. Applicants should write stating qualifications, experience, age and nationality to the Technical Director, Cottage Laboratories Ltd., Portsmouth Road, Cobham, Surrey. W 2119

VACANCY. Transformer Electrical and Mechanical Inspector required to take charge of department. Audio and Mains up to 50kVA. Box No. W 1620.

VACUUM PHYSICIST required for interesting and original work in the investigation of practical problems associated with large valve and mercury arc rectifier manufacture. Previous experience in this particular field desirable but not essential. Successful candidate will be required to work on own initiative and to exercise originality of approach in the development of test equipment and control of manufacturing processes. Salary commensurate with qualifications. Pensionable. Apply quoting reference AJFC to Box No. W 2173.

YOUNG ENGINEERS with University Degree or equivalent qualification required for interesting work on scientific and industrial instrumentation. Apply giving personal details and salary required to Cambridge Instrument Co. Ltd., Sydney Road, Muswell Hill. W 1597

SITUATIONS WANTED

B.A. HONS. (35), travelled, wide experience electronics development, requires sales or liaison work, U.K. or overseas. Box No. W 1631.

B.Sc., 10 years' experience industry and research, seeks work in electronic engineering applied to medicine, or allied work in both. Box No. W 1628.

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ELECTRONIC COMPONENT SUPPLIES. We specialize in the supply of Electronic Components, Accessories, Test Equipment, etc., for Government Depts., Industrial Concerns, Research Establishments, Laboratories, Colleges, etc. Your enquiries and orders will receive our prompt attention. Holiday & Hemmerdinger Ltd., 74/78 Hardman Street, Deansgate, Manchester, 3. Tel.: Deansgate 4121. W 148

94 COPIES "E.E." 1942-52. What offers? J. Nockles, 59, Crispin Crescent, Beddington, Croydon, Surrey. W 1618

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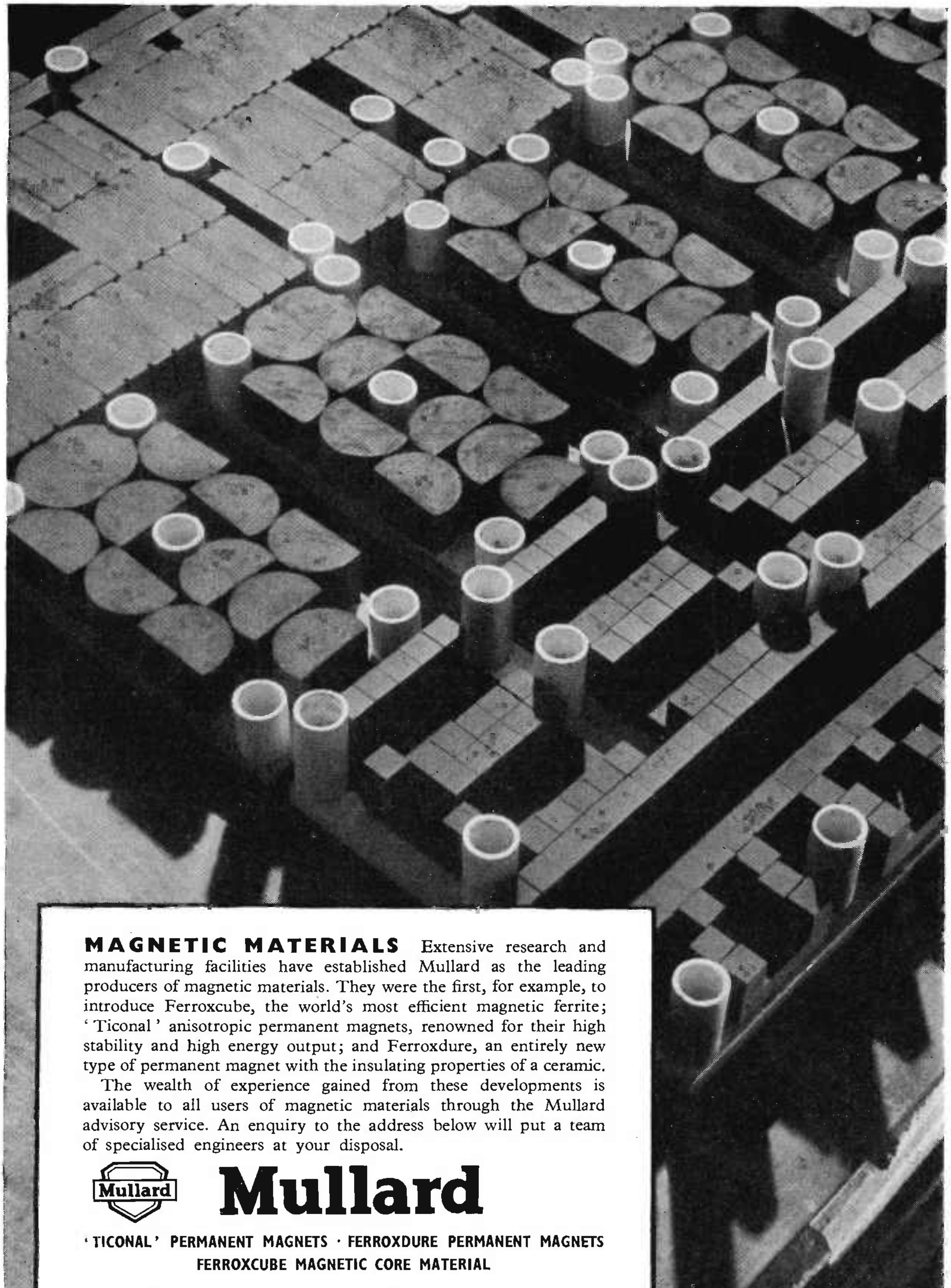
IT IS DESIRED to secure the full commercial development in the United Kingdom of British Patent No. 594,799 which relates to "Telemetering Systems", either by way of the grant of licences or otherwise on terms acceptable to the Patentee. Interested parties desiring copies of the patent specifications should apply to Stevens, Langner, Parry & Rollinson, 5 to 9, Quality Court, Chancery Lane, London, W.C.2. W 2135



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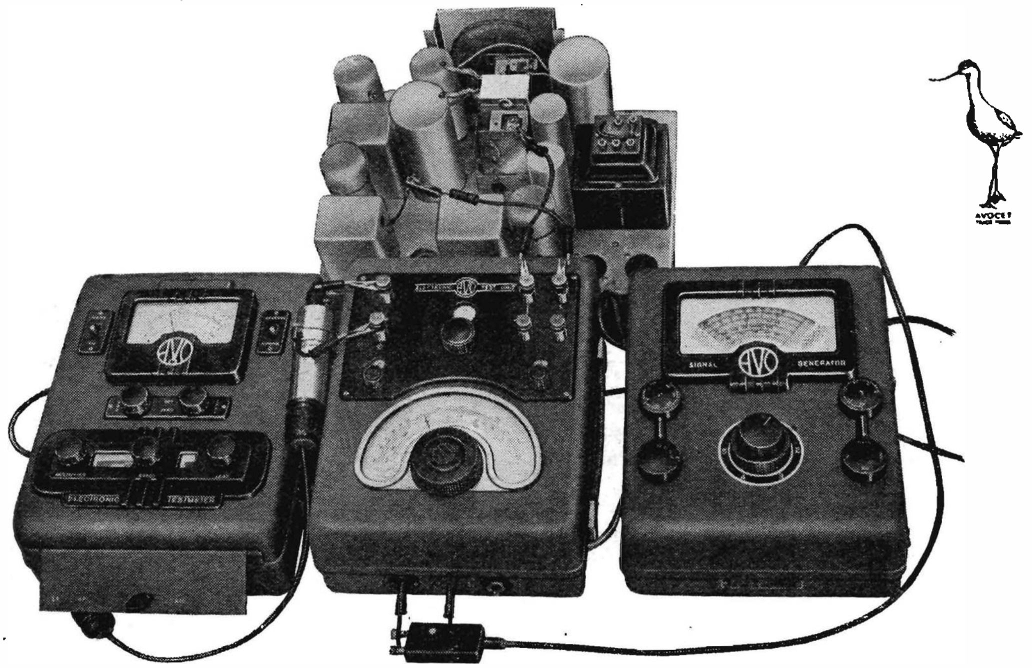

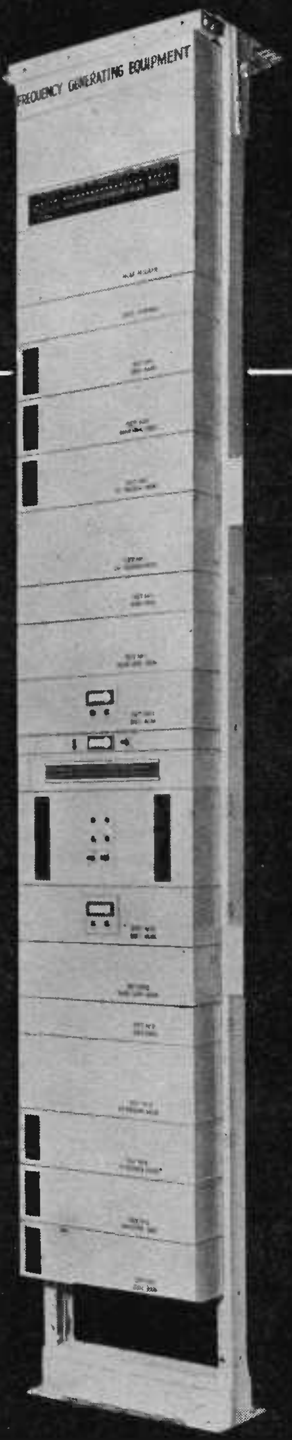
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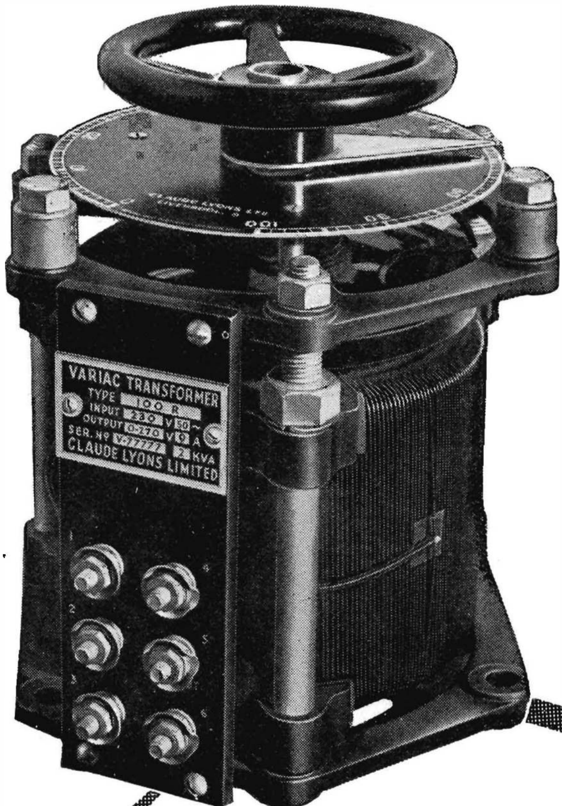
'VARIAC' voltage regulating transformers

Reg'd Trade Mark



'VARIAC' infinitely variable voltage-regulating transformers are designed and constructed for many years of trouble-free operation. Not only do they supply perfectly smooth control of voltage from zero, but many types (including 100-R) also furnish output voltages considerable above line voltage while the 100-RM/2B is a dual output type. Illustration left shows Type 100-R, Rating 2,000 va., Input Voltage 230/115, Output Voltage 0-270.

Left—
Type 200 C.U.H.

Right—
Type 50-B.

SERIES 100 'VARIAC' TRANSFORMERS.

Type	Load Rating	SPECIFICATIONS				No-Load Loss	Net Price ‡
		Input Voltage	Current		Output Voltage		£ s. d.
			Rated	Maximum			
100-K	2000 va.	115	15 a.	17.5 a.	0-115	20 watts	17 17 0
100-KM	2000 va.	115	15 a.	17.5 a.	0-115	20 watts	18 12 0
100-L	2000 va.	230/115	8 a.	9 a.	0-230	25 watts	17 17 0
100-LM	2000 va.	230/115	8 a.	9 a.	0-230	25 watts	18 12 0
100-Q	2000 va.	115	15 a.	17.5 a.	0-135	20 watts	18 9 0
100-QM	2000 va.	115	15 a.	17.5 a.	0-135	20 watts	19 4 0
100-R	2000 va.	230/115	8 a.	9 a.	0-270	30 watts	18 9 0
100-RM	2000 va.	230/115	8 a.	9 a.	0-270	30 watts	19 4 0
100-LH	1200 va.	480/240	2 a.	2.5 a.	0-480	25 watts	21 15 0
500-L *	1450 va.	180	8 a.	9 a.	0-180	25 watts	17 17 0
2000-K †	1000 va.	125	8 a.	9 a.	0-125	25 watts	17 17 0

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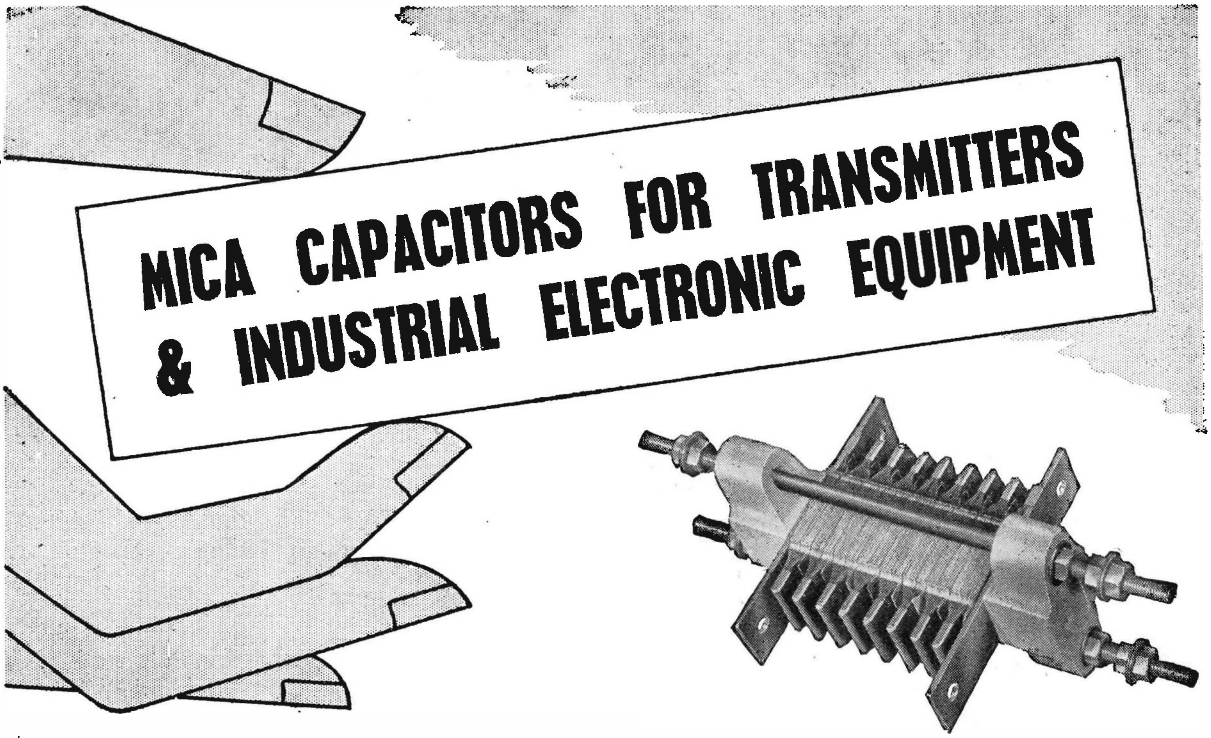

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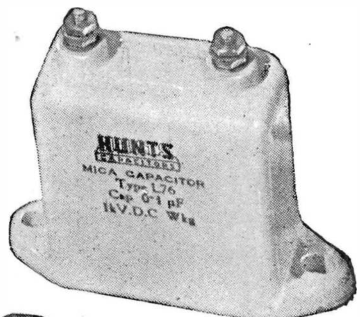
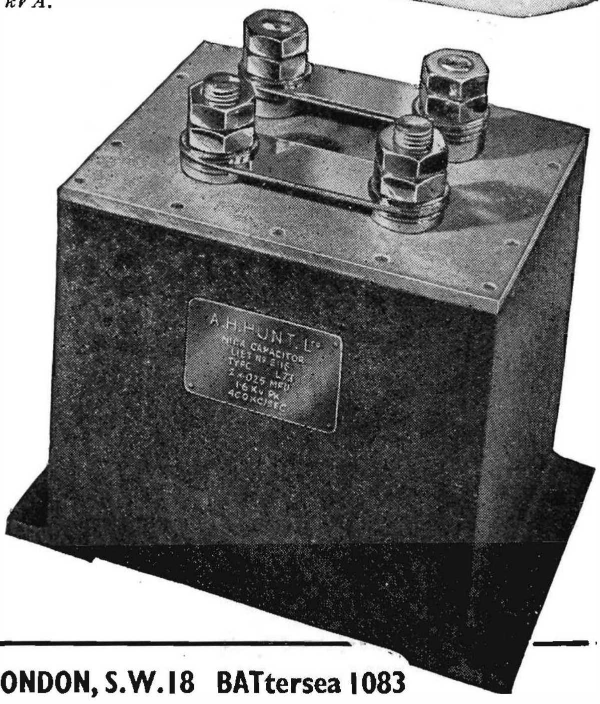
Alternative to oil filled tanks for handling considerable R.F. Power in limited space.



PORCELAIN CASED TYPE L76
Range includes ratings up to 10 kVA and D.C. Voltages up to 10 kV peak.

METAL TANK TYPE L73—oil filled—for application where the R.F. conditions exceed 10 kVA.



Mica capacitors designed and built to handle R.F. power are available in a variety of housings and sizes. The range includes open clamp construction and stacked mica types in porcelain or metal tank containers.

The standard range of metal tank types covers four sizes of cast aluminium containers and is extended with steel and non-ferrous tanks.

A greatly improved Mark 51 version of the HUNT-INGRAM (Mycalex product) type of R.F. Capacitor is now available. Full details on request.

The very special nature of these types, however, means that to provide for efficiency and economy in use, specific designs must often be prepared to meet individual needs. Hunts specialise in such work and enquiries from designers are most welcome.

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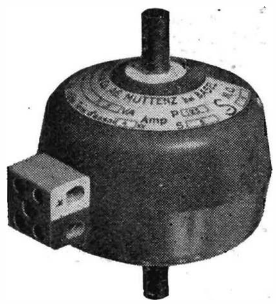

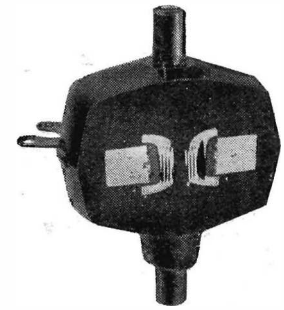

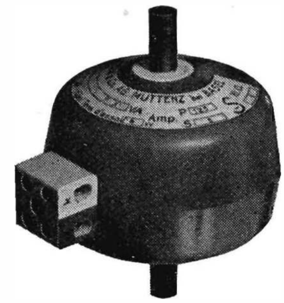

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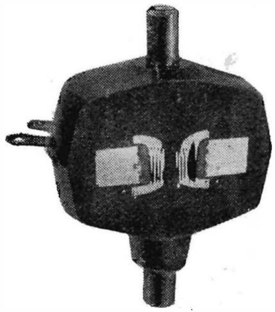

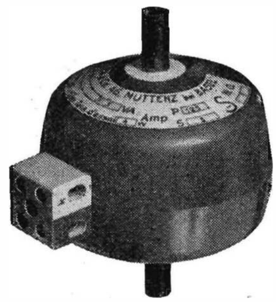

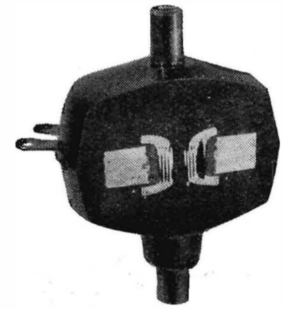

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'ARALDITE' is a hot-setting resin proved by experience to be eminently suitable for large-scale production. Its shrinkage during casting is very low, as no water or volatile products are given off during setting.

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Full details of properties, casting temperatures and curing times will be supplied gladly on request.

NOTE: 'ARALDITE' (Regd.) is also available in the form of hot-setting adhesives ('Araldite' Types 1 and 15) for bonding metals, porcelain, quartz, etc., and as a surface coating resin ('Araldite' 985E) for use as a primer or lacquer for light alloys.

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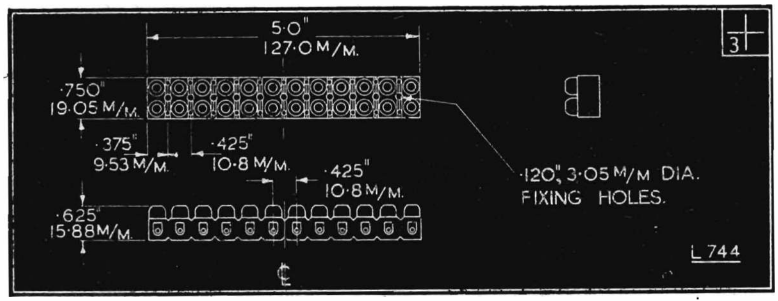
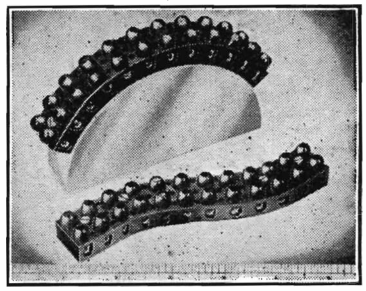
The "Belling-Lee" page for Engineers





List No. L. 744

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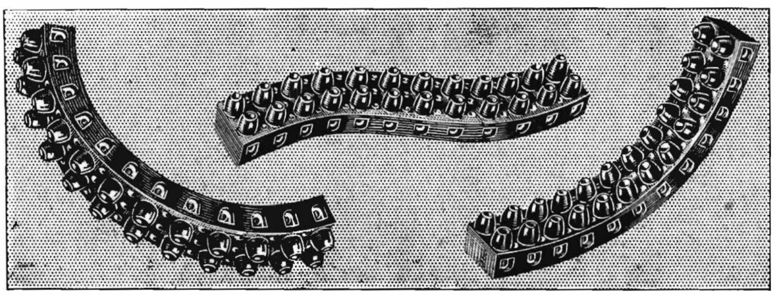
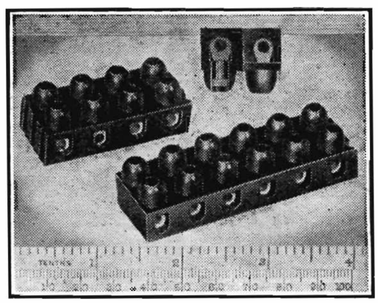
A UNIQUE 5-AMP FLEXIBLE TERMINAL BLOCK

Engineers, designers, and those in close touch with radio and electronic instrumentation, have been quick to appreciate the numerous possibilities and applications of this versatile component, which represents an entirely new departure in terminal block design.

First shown at the R.E.C.M.F. Exhibition, this terminal block aroused considerable interest, which has progressively increased in recent months.

Moulded in P.V.C., and in consequence very flexible, the moulding securely grips the terminal screws, which are so





dimensioned that they cannot fall out, *even if totally unscrewed from their inserts and the block mounted upside down.*

A very useful feature of this component is its great flexibility in both planes, which enables it to be snugly secured to irregular surfaces or over uneven contours.

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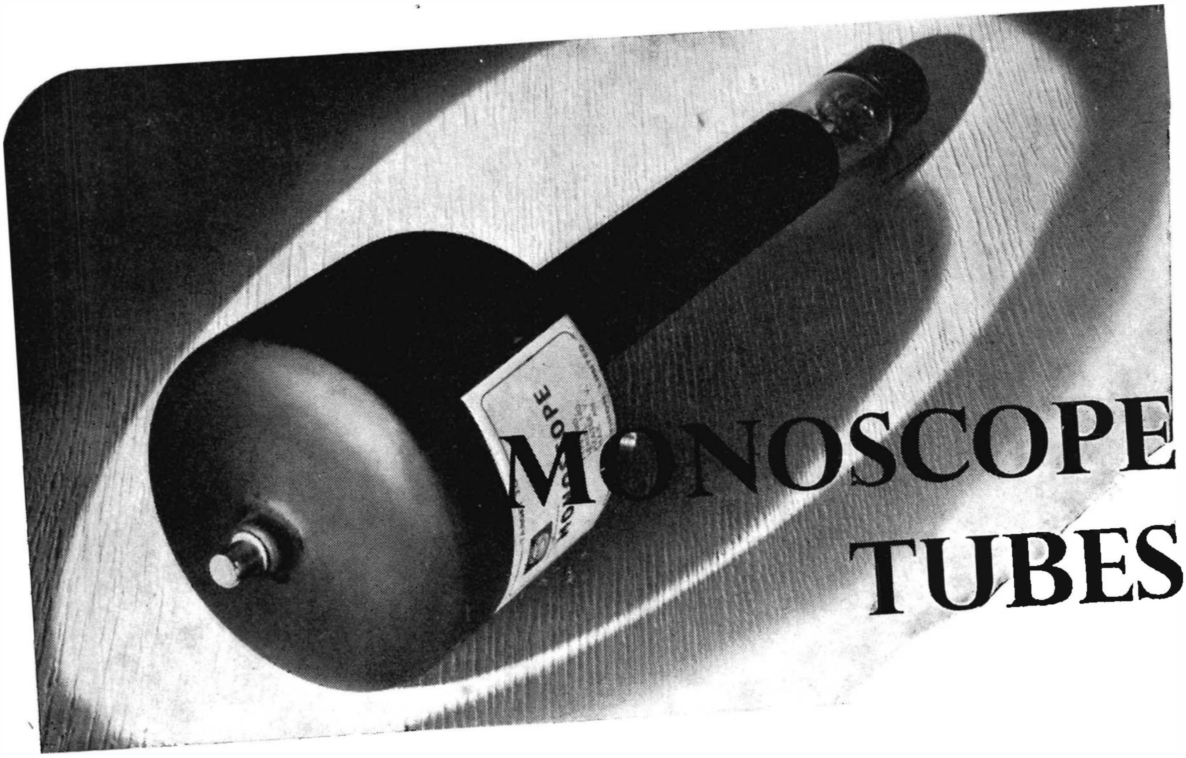

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Electronic Engineering

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

Vol. XXV JANUARY 1953 No. 299

Contents

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

Phone: CENTRAL 6565. Grams: 'LECTRONING, ESTRAND, LONDON'

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

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Electronic Engineering

Vol. XXV **JANUARY 1953** No. 299

Commentary

JUST how many pages should there be in a monthly periodical dealing with a scientific subject such as electronics ?

This question naturally springs to mind, and we are tempted to pose one or two others, after reading a short note entitled " Arithmetic " which appears in the December issue of our American contemporary *Electronics*.

Each editorial page of that journal, so the note says, is equal in content to two average pages of a modern technical book and as the December issue contains 125 such pages it is the equivalent of a 250 page book. On the basis of a two year subscription one gets all this, the note goes on to say, for about half the price of an old-fashioned shave and haircut!

We must, of course, offer our sincere congratulations on the appearance of this monumental issue which, with advertisements, totals some 460 pages, but quite naturally we have done some arithmetic on our own account to see how we stand by way of comparison. In sterling a two year subscription to *Electronics* costs ten guineas, so that a single copy costs nearly 9s.; whereas our own journal costs 2s. an issue—again about half the price of an old-fashioned shave and haircut in Britain. So that at this point there is little to choose, but to carry the comparison a stage further, during 1952 we averaged 49 editorial pages per issue, which works out, if our arithmetic is again correct, to a halfpenny an editorial page as against seven-eighths of a penny per page of *Electronics*.

This would appear to be much more in our favour. But in a more serious vein, is this really a basis for comparison, and indeed should this comparison be made at all ? We are inclined to think that the answer is no to both questions.

Certainly the American electronic industry is much larger than its British counterpart and it is logical to assume therefore that an American journal may expect to receive more editorial contributions from the industry which it represents.

But the number of pages of most technical periodicals is governed by a number of factors other than size—or importance—of the science or industry and these usually fall under the heading of income and expenditure. Is there an optimum size for a journal which month by month surveys its own particular branch of science ? And who is to judge what is the optimum—the reader, the publisher, the advertiser ? Just how much, too, can the average reader be expected to assimilate each month ?

We, who occupy ourselves each month with the preparation of our own journal, find that an immense amount of time can be taken up with the reading of current literature and our sympathy is extended to the man who has not only to attempt the same task but has a job to do at the bench as well.

* * *

Some fourteen camera units of the Crown Film Unit journeyed last year to the Monte Bello Islands off the N.W. coast of Australia and made a complete film record of the operations there from the initial landing preparations to the final explosion of Britain's first atomic weapon. Many thousand feet of film were taken and the Ministry of Supply has just released sections of this record for public showing on television and newsreels.

This film, some eight hundred feet long, opens with some scenes of the inhospitable Monte Bello Islands and continues with the preparatory work carried out by the British Forces, in conjunction with Commonwealth Forces —notably the Royal Australian Navy and Air Force—in the construction of landing piers, beach heads and so on, and ends with some terrifying scenes of the explosion itself.

Admittedly many aspects of the operation have to be clothed in secrecy, and a public showing of the complete film would be most inadvisable, but the shortened version which many of us will have now seen has left us with an appetite for more. We hope that it may be possible for the Ministry of Supply to release more of the original record and so compile a reasonable length documentary covering those technical aspects which do not conflict with security.

* * *

Our attention has been called to the commentary in the November issue of ELECTRONIC ENGINEERING in which we referred to the post-war television transmitters of the BBC. We stated that Kirk o'Shotts and Wenvoe were both operating on the low-power standby transmitters whereas, in point of fact, Kirk o'Shotts since its opening last summer has been operating on high power. Our apologies are due for this affront to Scotland.

Time-Division Multiplex Systems

(Part 1)

By J. E. Flood* Ph.D., A.M.I.E.E.

This series of articles is an introduction to the principles of time-division multiplex communication systems and the circuits employed. Part 1 describes the different forms of pulse modulation which can be used and discusses the features which are common to T.D.M. *systems in general. Part 2 describes in more detail the particular features of pulse-amplitude modulation, Part 3 describes pulse-length and pulse-position modulated systems and Part 4 deals with pulse-code modulation.*

MULTI-CHANNEL communication systems are of two basic types; those in which the individual channels are used to modulate different carrier frequencies, and those in which the channels are connected to the transmission path at different times. The first type can be called frequency-division systems and the second type are called time-division multiplex systems[1,2,3,4]. The time-division method of multiplexing was used in the Baudot system of multiplex telegraphy[5] in 1874. Later the invention of the electric wave filter and the thermionic valve made frequency-division multiplexing practicable and carrier transmission became the standard method both for multi-channel telephony and telegraphy. The development of pulse techniques led to some revival of interest in T.D.M. before the last war[4] and the use of U.H.F. pulse transmission for radar during the war led to the development of practical T.D.M. radio links.

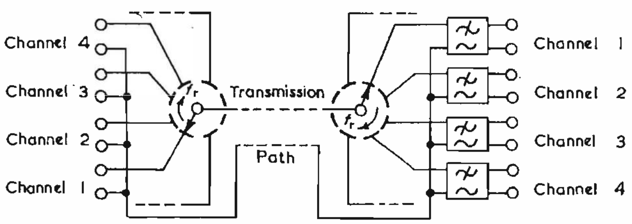

Fig. 1. Elementary T.D.M. system

The elementary time-division multiplex system shown in Fig. 1 consists of a transmission path, at each end of which is connected a rotating switch. The two switches rotate in synchronism, so that the sending and receiving apparatus of each channel are connected together for their allotted time interval and disconnected throughout the remainder of each revolution of the switch. In order to fill in the gaps between the " samples " of signal, the receiving circuit must have a integrating action, such as is inherent in a low-pass frequency characteristic.

The Baudot multiplex telegraph system employed mechanical switches, and these are still used for telegraph systems[5,6] and for some multiplex telemetering systems[7,8,9], but the frequency of switching required for T.D.M. telephone systems is too high for mechanical methods. Rotating electron beam tubes[10,11,12,13] have been used to provide an electronic equivalent of the rotating switch and may ultimately prove the best solution of the problem, but switching is quite practicable by means of gating circuits using conventional valves. Each channel is connected to the common path by a valve which is normally biased beyond cut-off but is rendered conducting periodically by a pulse train.

The form of signal which is transmitted by the T.D.M. system of Fig. 1 consists of interlaced trains of pulses of identical repetition frequency, each pulse train being amplitude-modulated by the signal of one channel as shown in Fig. 2(b). The frequency spectrum of a train of amplitude-modulated pulses can be shown[1] to consist of components at the frequencies comprising the modulating signal, together with the pulse repetition frequency (P.R.F.) and its harmonics and upper and lower sidebands about the P.R.F. and each harmonic, as shown in Fig. 3. In order to demodulate the signal, a low-pass filter can be used to suppress all components except those identical with the original signal. For this to be possible, the lower side-

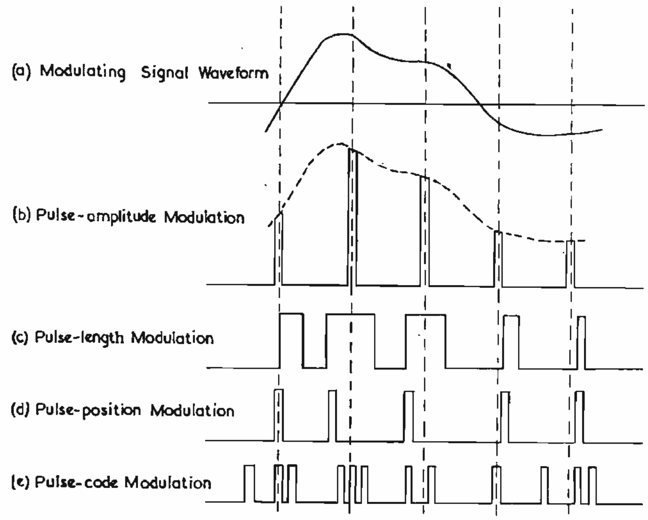

Fig. 2. Methods of pulse modulation

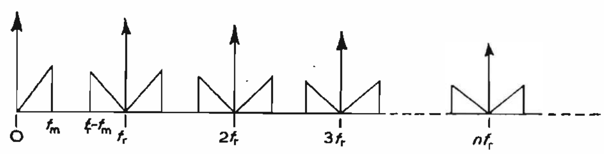

Fig. 3. Frequency spectrum of a train of amplitude-modulated pulses

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band of the P.R.F. must not overlap the frequency band of the modulating signal, so the pulse repetition frequency must be at least twice the highest frequency of the modulating signal.

Types of Pulse Modulation

Several methods besides pulse-amplitude modulation (P.A.M.) are available for modulating pulse trains, and the chief of these will now be considered. In pulse-length modulation* (P.L.M.), pulses of constant amplitude are made to vary in length by the modulating signal. In Fig. 2(c) the rear edge of each pulse occurs at a fixed time in the cycle and the length of the pulse is modulated by varying the time at which the front edge of the pulse occurs. All the information contained in the modulating signal is conveyed by the position of the front edge of the pulse, so sending the flat top portion of the pulse is really a waste of transmitter power. The same information can be transmitted with less power by using much shorter pulses of equal amplitude and length whose times of occurrence are advanced or retarded by the modulating signal as shown in Fig. 2(d). This system is generally known as pulse-position modulation (P.P.M.) (sometimes called pulse-time or pulse-phase modulation).

In pulse-frequency modulation (P.F.M.), the repetition frequency of a train of identical pulses is varied by the modulating signal. Pulse-frequency modulation is unsuitable for T.D.M. working because interlacing of the pulse trains of the different channels can only be maintained if they all have the same repetition frequency. It is, of course, possible to multiplex a number of channels using frequency-division and then to use the resulting signal to modulate the repetition frequency of a pulse train. P.F.M. has also been used for a 3-channel telemetering system by using for each channel a pulse of a different length and having at the receiving end apparatus for each channel which accepts only pulses of the appropriate length.[14] Various other pulse systems of multiplexing which do not use synchronous time-division are also possible[15,16,17].

P.F.M. causes the pulse density per unit time to be varied in accordance with the modulating signal by altering the P.R.F. The pulse density can, however, be varied by making systematic omissions without changing the timing of the transmitted pulses, thus permitting synchronism to be maintained. Omitting every other pulse corresponds to zero modulation and re-inserting one or more pulses corresponds to a positive modulating signal. This system[18] is known as pulse-number modulation (P.N.M.). In order to transmit a reasonable number of gradations of amplitude the P.R.F. must be very much greater than the highest modulating frequency; P.N.M. therefore requires a much greater bandwidth than other methods of pulse modulation and is not used for T.D.M. systems.

A method of pulse modulation called delta modulation has been described by L. J. Libois[19]. Every time a channel is sampled, a pulse is sent only if the signal has increased since the previous pulse was sent; if the signal has decreased, no pulse is sent. Omitting every other pulse corresponds to no change of modulation and re-inserting pulses correspond to an increasing modulating signal. The P.R.F. must again be much greater than the highest modulating frequency.

In binary pulse-code modulation (P.C.M.), a group of pulses is sent, each of which may be present or omitted as shown in Fig. 2(e). The number of possible combinations of a group of q pulses, omitting any number of them between 0 and q is 2^q, thus 2^q is the number of amplitude gradations which may be sent over the system. For example, if q is 7 it is possible to distinguish between 128 different values of modulating signal, whereas a P.N.M. system would only be able to transmit eight gradations of amplitude with the same number of pulses.

** This method is also sometimes called pulse-width or pulse-duration modulation.*

The chief methods of pulse modulation have now been described but other methods are possible and combinations of various methods have sometimes been used. It has, for example, been proposed to double the number of channels of a T.D.M. system by using position-modulated pulses to switch on and off a carrier, each pulse of which is frequency-modulated by another channel[20]. Another method[21] is to use P.L.M. with the front edge of each pulse modulated by one channel and the rear edge by another.

For the transmission of T.D.M. over a radio link the transmitter is usually amplitude-modulated, the carrier being switched on and off by the pulses, but frequency-modulation of the carrier by the T.D.M. system has been used[22]. T.D.M. systems, such as P.P.M., which use pulses of constant amplitude are usually used instead of P.A.M.; they have considerably better signal-to-noise ratios because the receiver has only to detect the time for which each pulse is present and can be unaffected by amplitude-modulation of the pulses by noise. The greatest immunity from noise is obtained with systems, such as binary P.C.M., in which the receiver has only to detect the presence or absence of each pulse and so can be unaffected by small displacements caused by noise on the rising and falling edges of the pulses as well as being insensitive to amplitude variations. A greater bandwidth is required than for simpler systems, such as P.P.M., because of the greater number of pulses per second which must be transmitted for each channel.

Comparison between Carrier and T.D.M. Systems

For separating the frequency bands of the different channels a multi-channel carrier system requires a large number of band-pass filters. If the frequency separation between adjacent channels is small the specifications for the filters must be very stringent; moreover each channel occupies a different frequency band and so requires a different design of filter. The numbers of filters made to each design are not usually very large, so they are naturally expensive. In time-division multiplex systems, the channels are separated by gate circuits which use valves and ordinary resistors and capacitors with wide tolerances; moreover each channel uses an identical circuit. The only filters used are the low-pass filters which are identical for each channel and usually do not require to meet very stringent requirements.

In multi-channel carrier systems, intermodulation products caused by non-linear distortion result in interference between the signals of different channels. The amplifiers used must therefore be much more linear than those required for a single channel and radio transmitters are usually compelled to use only a small depth of modulation, thus making it more difficult to obtain an adequate signal-to-noise ratio. Non-linear distortion does not cause inter-channel crosstalk in a T.D.M. system because the signals of the different channels are applied independently to the amplifiers at different times. Consequently the linearity requirements of a T.D.M. system are no more stringent than those for a single-channel. Attenuation and phase distortion do not cause crosstalk in multi-channel carrier systems, whereas in T.D.M. systems they cause the pulse waveforms to spread in time so that the received pulses interfere with each other. A T.D.M. system therefore has much more severe attenuation and phase requirements than a carrier system and usually requires a much greater total bandwidth. All the methods of pulse modulation considered, except P.A.M., do, however, give an improvement in signal-to-noise ratio (compared with amplitude-modulation) as a result of their increased bandwidths.

Carrier systems are more suitable than T.D.M. for multi-channel systems on cables because of the limited bandwidth available and the difficulties of accurately equalizing the attenuation and phase characteristics and avoiding reflexions due to impedance irregularities. Successful T.D.M. working on open-wire lines has been obtained[23] by adapting the technique of transmitting curbed pulses which is used in D.C. telegraphy[5]. The wide bandwidth required also makes T.D.M. systems unsuitable for radio links using low or medium frequencies. U.H.F. radio links, however, have ample bandwidth to accommodate T.D.M. systems and the resultant improvement in signal-to-noise ratio is an important advantage. Moreover, many of the valves used for the generation of U.H.F. waves are unsuitable for amplitude- or frequency-modulation but are eminently suitable for producing constant-amplitude pulses.

In a trunk telephone system consisting mainly of carrier cable routes the radio links used are likely to use frequency-division in order to avoid having to demodulate the signals at every point where a carrier system is connected to a radio system. In a trunk system consisting mainly of radio links, however, such interconnexions would be fewer and it would be economical for the radio links to exploit the advantages of T.D.M. Moreover, it is likely under such conditions that T.D.M. would be extended into the coaxial cable network using some form of P.C.M.

T.D.M. Switching

An advantage of T.D.M. is the ease with which one or more channels can be separated from the system for transmission over a different route. Any channel can be separated from a T.D.M. system without affecting the others by means of a gate operated by the appropriate pulse train, whereas with a carrier system it is usually difficult to divert a few channels at an intermediate point on the route. The suitability of T.D.M. systems for switching speech channels from one route to another is, in fact, likely to lead to the development of electronic telephone exchanges based on the principle of T.D.M.[4,24]. A telephone exchange could be constructed by connecting together several ranks of switches, each of which consisted of a T.D.M. system with the gates at one end of the system connected directly to those at the other end. If each gate at one end is supplied with a pulse-train which occupies a fixed position in the cycle and each gate at the other end is supplied with a pulse-train which can be made to occupy any position in the cycle, then any channel at one end of the switch can be connected to any of the channels at the other end.

Multiplex Broadcasting

If the V.H.F. and U.H.F. bands are used for broadcasting, the optical range of propagation will make it essential for transmitter aerials to be sited on high ground. Suitable sites are limited so, if several alternative programmes are required, it is advantageous for these to be radiated from a single aerial at the best possible site in the area. Fixed-tuned receivers can then be used with directional aerials. For these reasons it is desirable for the alternative programmes to be multiplexed on a single carrier. T.D.M. should be preferable to a frequency-division multiplexing for this purpose[25,26] because the receivers need use only cheap components whereas receivers for frequency-division multiplex would require very stable local oscillators and expensive filters. H. L. Kirke[27] concluded, however, that frequency-modulation on different wavelengths was preferable.

Pulse Generation and Synchronization

In order to operate the gates of the channels comprising a T.D.M. system it is necessary to generate a set of channel-pulse trains whose pulses are spaced at equal intervals throughout the pulse repetition cycle. One way of generating the channel-pulses is to use a sinusoidal master oscillator to trigger the pulse generators, each through a separate phase-shifting network[21,28]. The very accurate adjustment needed for the phase shifters makes this method unsuitable except when the number of channels is small.

Another way of generating the pulses is shown in Fig. 4; a set of pulse generators, such as flip-flop circuits or blocking oscillators, are connected to form a ring[3,29,30]. It can be arranged that the rear edge of the pulse generated by each circuit triggers the next circuit so that each generates a pulse in turn. In order to enable the channel-pulse generators to use components with wide tolerances and yet generate pulses which occur at exactly regular intervals, each generator is arranged to operate only when it receives simultaneous triggering pulses from the preceding generator and from a master pulse source. The master pulse generator has a P.R.F. equal to the channel P.R.F.

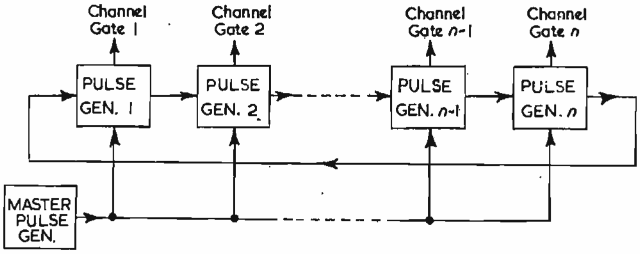

Fig. 4. Ring of pulse generators

multiplied by the number of channels; it can be crystal controlled in order to have a very stable repetition frequency.

Another way of providing the pulses required for the channel gates is to use an electric delay-line distributor[22,31,32] as shown in Fig. 5. The time delay of the delay-line is made equal to the channel-pulse repetition period and the channel gates are connected to the line at equal intervals along its length. The pulse generator which feeds the delay line is triggered by the output pulses from the far end and thus has the required P.R.F.; it is also locked to a master pulse generator. The pulse travelling along the delay-line becomes progressively distorted and is thus unsuitable for operating the channel gates directly. The gates are therefore arranged to operate only while simultaneously receiving a pulse from the distributor and from the master pulse generator (whose P.R.F. equals the channel P.R.F. multiplied by the number of channels).

At the receiver, the pulse generating equipment is usually driven from the incoming signal instead of an independent master pulse generator in order to keep the pulses in synchronism with those at the transmitter. For this purpose, one channel in the system is usually allotted to a distinctive signal, such as a specially long pulse or a combination of pulses, used for that purpose. The problem

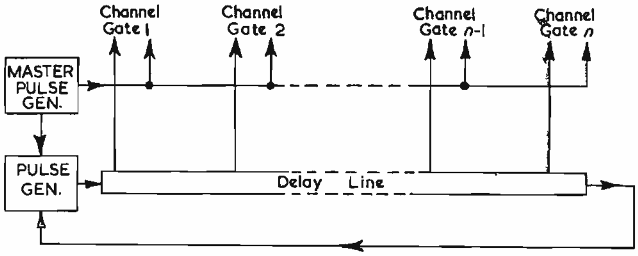

Fig. 5. Delay line pulse distributor

of recognizing the synchronizing signal is similar to that encountered in television.

One way of separating a long synchronizing pulse from shorter channel pulses is to use a differentiating circuit[30] as shown in Fig. 6. The differentiated positive spike which coincides with the rear edge of the long synchronizing pulse is of greater height than those produced by the shorter channel pulses. The valve is biased well beyond cut-off, so its anode current consists of short pulses whose front edges coincide with the rear edges of the synchronizing pulses.

Another method of detecting the synchronizing pulse is shown in Fig. 7. It uses a delay-line on which are two tappings separated by a time delay which is greater than the length of the channel pulses, but less than the length of the synchronizing pulse. Thus only the synchronizing pulse can cause an output to be received simultaneously from the two tapping points, causing the valve to pass a pulse of anode current. Delay-line circuits can also be constructed to detect synchronizing signals comprising a group of two or more short pulses instead of one long one[28].

The use of a synchronizing pulse whose length is much greater than the minimum allowed by the bandwidth of the system reduces the danger of impulsive noise causing

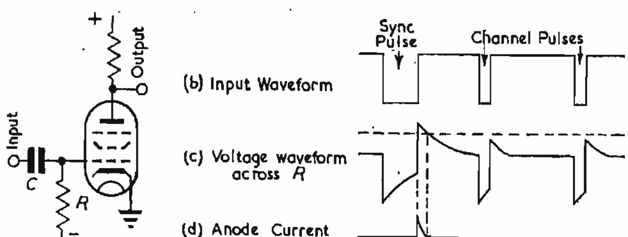

Fig. 6. Separation of synchronizing pulse by differentiating circuit

complete loss of the synchronizing pulse and interruption of all the channels. If the gating pulses are generated directly from the synchronizing pulse, however, noise present on the build-up and decay of this pulse will cause some jitter in the timing of the gating pulses resulting in noise on all the channels. Noise due to this cause can be minimized by including in the synchronizing apparatus of the receiver a circuit with a time-constant long compared with the pulse repetition period, thus obtaining a flywheel effect[8,33].

Synchronization is possible without sacrificing a channel of the system if the transmission performance of one channel may be degraded in order to accommodate an additional signal. Boothroyd and Creamer[22] have described a P.A.M. system in which the channel P.R.F. is 8kc/s and the synchronizing signal is a tone of 3·9kc/s which is used to modulate one of the channels in addition to its speech signal. This channel must have a smaller audio-frequency bandwidth than the others because of the filter used to extract the 3·9kc/s tone at the receiver. A Bell Telephone Laboratories P.C.M. system provides 12 channels, each of which is sampled with a P.R.F. of 8kc/s and each channel

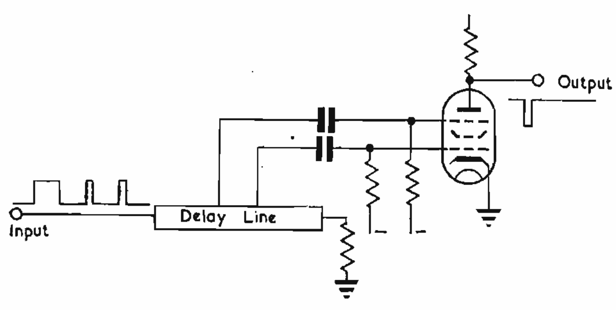

Fig. 7. Separation of synchronizing pulse by means of a delay line

uses a group of seven pulses. The first pulse position of the first channel is used for synchronization[34]; a pulse is inserted in that position in alternate cycles only, in order to obtain a large component at 4kc/s (one-half the P.R.F.). This channel can therefore only use six pulses for its speech signal and so can only transmit 64 amplitude levels instead of 128.

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(To be continued)

Multiplication
In the Manchester University
High-Speed Digital Computor

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This article gives an account of the method used for performing multiplication in the high-speed digital computor which has recently been built by Messrs Ferranti and installed at Manchester University[1].

BEFORE considering the multiplying system, or *multiplier* as it will be called, it is necessary to spend some time on the binary notation, which is used for numbers in the machine, and also on some details of the machine itself, which determine the form and operation of the multiplier. Further details may be found in the References[1,2,3,4].

In the binary notation for numbers the values of the successive digits of a number, beginning from the right-hand end, are one, two, four, etc., instead of one, ten, a hundred, as in the case of ordinary decimal numbers. Two variants of the binary notation are used in the machine. In the first, the *unsigned* notation, a number is interpreted by adding the values of all its digits. For example, 1011 represents $8+2+1$ or eleven. Only positive numbers can be represented in this way. In the second variant, the *signed* or *complement* notation[3], the value of the left-hand, or most significant, digit is subtracted from the sum of the values of the remainder of the digits. Both positive and negative numbers can be represented. For example, eleven may be given as 001011 $(8 + 2 + 1)$, and minus eleven as 110101 $(-32 + 16 + 4 + 1)$.

It should be noted that, when a signed number is extended by adding more digits at the left-hand end, the correct procedure is to repeat the left-hand digit[4]. For example, if we extend them to eight digits, eleven becomes 00001011 and minus eleven 11110101. In the case of unsigned numbers, and in the case of all numbers extended at the right-hand end, the added digits are always 0's.

An advantage possessed by the complement notation for signed numbers is that the processes of addition and subtraction can be carried out by exactly the same methods on signed and unsigned numbers, if the units carried from, or borrowed by, the left-hand digit are ignored[3]. This holds provided that the input numbers have the same number of digits, and provided that the result can be expressed in that number of digits. Thus, when complement notation is used, only one set of adding and subtracting circuits need be provided, and these circuits need not be informed whether the numbers passing through them are signed or unsigned. Unfortunately this does not apply to multiplication, which must take account of the sign conventions of the factors.

The following example shows the addition of three unsigned binary numbers. The chief difference in the addition of binary and decimal numbers is that with binary numbers twos instead of tens are carried to the next column of a number.

$$\begin{array}{rr}
01011 & 8+2+1=11 \\
01110 & 8+4+2=14 \\
\underline{11100} & 16+8+4=\underline{28} \\
\underline{110101} & 32+16+4+1=\underline{53}
\end{array}$$

The right-hand column adds up to one, which is written in the answer line; the second column adds up to two—write 0 and carry 1; the third column (including the carry) adds up to three—write 1 and carry 1; the fourth column adds up to four—write 0 and carry 2; and so on.

An example of binary multiplication of unsigned numbers will now be given*:

$$\begin{array}{rll}
11011 & ..\ R=27 & (16+8+2+1) \\
\underline{10101} & ..\ D=21=\sum_{k=0}^{4} d_k 2^k & (16+4+1) \\
0000011011 & ..\ Rd_0 2^0 & \\
000000000 & ...\ Rd_1 2^1 & \\
00011011 & ....\ Rd_2 2^2 & \\
0000000 & .....\ Rd_3 2^3 & \\
011011 & ......\ Rd_4 2^4 & \\
\underline{1000110111} & ..\ RD=567=\sum_{k=0}^{4} d_k 2^k R & (512+32+16+4+2+1)
\end{array}$$

Three processes are involved:

1. The factor R is multiplied separately by each digit, d_k, of the factor D.
2. The products Rd_k are each multiplied by 2^k.
3. The products $Rd_k 2^k$ are added to form the final product.

It will be seen that each of the $Rd_k 2^k$'s is extended to the tenth column by adding 0's, since R is unsigned. If R is signed, the $Rd_k 2^k$'s must be extended by repeating the left-hand digit. Again, if D is signed, the product $Rd_4 2^4$, corresponding to the left-hand digit of D, must be reversed in sign before being added, since d_4 now has a negative significance. An example of multiplication of signed numbers will now be given:

$$\begin{array}{rl}
11011 & ..\ R=-5 \\
\underline{10101} & ..\ D=-11=\sum_{k=0}^{3} d_k 2^k - d_4 2^4 \\
1111111011 & ..\ Rd_0 2^0 \\
000000000 & ...\ Rd_1 2^1 \\
11111011 & ....\ Rd_2 2^2 \\
0000000 & .....\ Rd_3 2^3 \\
\underline{000101} & ......\ -Rd_4 2^4 \\
(1\ 0)\underline{0000110111} & ..\ RD=55 \text{ (units carried from the tenth place are ignored)}
\end{array}$$

Representation of Numbers as Pulse-trains

In the Manchester machine binary numbers are transferred between parts of the machine as pulse-trains, in which a pulse represents 1 and the absence of a pulse 0. The machine divides time into periods of 240μsec which are known as *beats*. Each beat is divided into 24 *digit-*

* *Ferranti, Ltd.*

* *In a similar example given in Reference 4 the letters R and D are reversed The reason for the reversal will be made clear later.*

periods of 10μsec. The first four digit-periods of a beat (the *black-out period*) are blank, and during the remaining twenty digit-periods a twenty-digit number may be specified by a pulse-train occurring at a point in the circuits. Fig. 1 shows how this is done. A pulse in digit-period 0 gives the units digit of the number as 1, a pulse in digit-period 1 gives the two's digit as 1, and so on. If

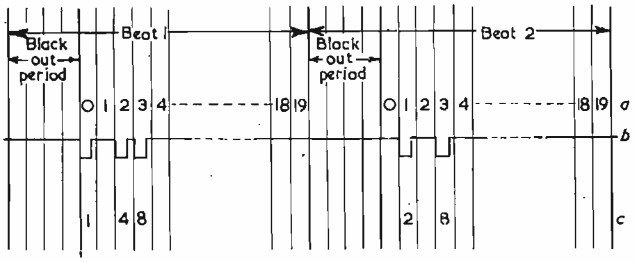

Fig. 1. The representation of numbers as pulse-trains

(a) Numbers of digit-periods.
(b) Pulse-train representing numbers. (The pulses are negative-going).
(c) Values of pulses.
The pulse-train (b) gives in beat 1 1+4+8=13, and in beat 2 2+8=10.

a number has more than twenty digits, it must be transferred as a pulse-train extending over more than one beat. The pulse-train shown in the Figure may represent either 1 + 4 + 8 (= 13) in the first beat and 2 + 8 (= 10) in the second, or 13 + 10 $\times$ 2^{20}, if the pulse-train is taken as representing one number in the two beats.

The Storage of Numbers

Numbers are stored in the multiplier and in the associated parts of the machine by a system of cathode-ray tube storage due to Prof. F. C. Williams and Dr. T. Kilburn[2]. Fig. 2 shows the features of such a store that are relevant to this article. For the purposes of this article the storage tube may be taken as a device which stores several twenty-digit binary numbers, each in a separate location or *line*. In every beat one of these lines is *scanned* under the control of a line selecting circuit, and the number stored there appears as a pulse-train at a *read output* terminal. This is the process of *reading*. To record or *write* a number in the store, the desired line is scanned and the new number is fed as a pulse-train to the *write input* terminal of the store. If it is desired to read a line without changing the number stored on that line, the write input of the store is connected to the read output, so that, when the line is scanned, the number in it is rewritten in the same line.

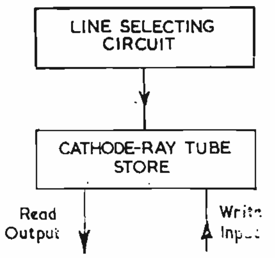

Fig. 2. Simplified block diagram of cathode-ray tube store

Organization of the Machine

Fig. 3 shows in schematic form the parts of the machine which are concerned with multiplication. The *main store* consists of eight cathode-ray tube stores, each having 65 twenty-digit lines. The contents of these lines may be treated as

(1) simple twenty-digit numbers,
(2) forty-digit numbers occupying two adjacent lines,
(3) instructions, which are coded as twenty-digit numbers.

Control withdraws the instructions from the main store as they are required and sends signals to other parts of the machine (shown as broken lines in the Figure) which cause the operations called for by the instructions to take place.

The *accumulator* is a cathode-ray tube store holding a single eighty-digit number, the result of arithmetical and other operations, in four twenty-digit lines, 0, 1, 2, and 3. Line 0 holds the twenty least significant digits, line 1 the twenty next least significant, and so on. There is a line selecting circuit which normally scans the lines in successive beats in the cyclic order 0, 1, 2, 3. When it is required to read the number from the accumulator, the line selecting circuit is constrained at the beginning of a beat to scan line 0. Then the twenty least significant digits will be read in that beat, and the remaining digits will follow automatically in the next three beats as the line selecting circuit continues its cyclic scanning of the lines.

The read output and write input terminals of the accumulator are connected by several paths, each of which is controlled by a gate. Three paths are shown at the right of the schematic diagram, Fig. 8. The first, controlled by the gate 5, allows the contents of the accumulator to be rewritten unchanged; the second (gate 6) causes the read output pulse-train to be combined in an adding circuit with a pulse-train coming from the main store or from the multiplying circuits, so that the sum of the numbers represented by the pulse-trains is recorded in the accumulator in place of the original contents. The third path (gate 7) similarly causes a difference to be formed. After a series of operations have been performed in the accumulator, the number stored there may be transferred to the main store.

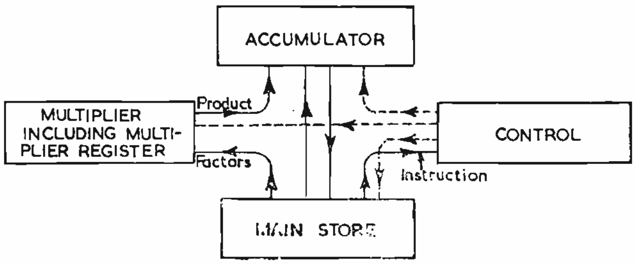

Fig. 3. Block diagram of computing machine

Full lines give the paths by which numbers may be transferred; broken lines indicate signals from control

The *multiplier* forms the product of two numbers sent from the main store, and sends it to be added or subtracted into the number in the accumulator. The multiplier contains the *multiplier register*, which is a cathode-ray tube store holding the two forty-digit factors R and D, in four twenty-digit lines, m_r, m_r', m_d, m_d'. There is a line selecting circuit which causes the lines to be scanned in successive beats in the cyclic order given above. This circuit can be constrained in the same way as the accumulator line selecting circuit to scan a particular line in a given beat.

Operational Cycle of the Machine

The operation of the machine is divided into *bars*, which consist of four or more beats. In each bar one instruction is withdrawn from the main store and obeyed. The beats of a bar have names, which are given at *a* in Figs. 6 and 7.

The first three beats, which are called S_1, A_1, and S_2, are occupied by finding the instruction to be performed and transferring it to control. Signals indicating the nature of the operation to be performed are made available by control at the end of S_2, and remain available until the end of A_1 of the following bar.

The remainder of the bar, which may be of one or more beats, is occupied by performing the operations ordered by control. The beat following S_2 is called A_2; further beats, when they exist, are called A_3, S_3, B_5, S_5, S_6, S_7 and B_8. In the bar shown in Fig. 7 all these beats are present, although the last two are allowed to overlap, and coincide with S_1 and A_1 of the following bar.

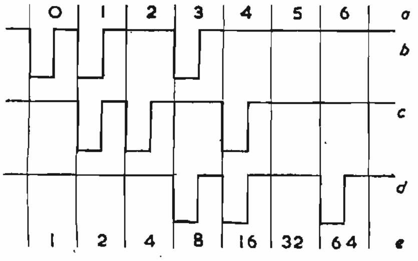

Fig. 4. Multiplication by powers of two

(a) Number of digit-period.
(b) Pulse-train giving $1+2+8=11$.
(c) Pulse train shifted by one digit-period, giving $2+4+16=22=11\times 2^1$.
(d) Pulse-train shifted by three digit-periods, giving $8+16+64=88=11\times 2^3$.
(e) Values of pulses.

The Multiplication Instructions

Multiplication takes place in two steps. In the first step the multiplier D, is transferred from the main store to the multiplier register†, where it is held until further notice. This operation will be referred to as the D-operation. In the second step (the R-operation) the multiplicand, R, is transferred from the main store to the multiplier†, which forms its product with D and adds, or subtracts*, it into the number in the accumulator. It should be noted that D remains in the multiplier register until it is superseded by a number from the main store in the next D-operation. Thus any number of multiples of D may be added into the accumulator by a series of R-operations, of which only the first need be preceded by a D-operation.

Before it can form a product the multiplier must be given the following information:

1. The digits of the factors R and D.
2. The sign conventions of the factors, which are not necessarily the same.
3. Whether the product is to be added to or subtracted from the number in the accumulator.

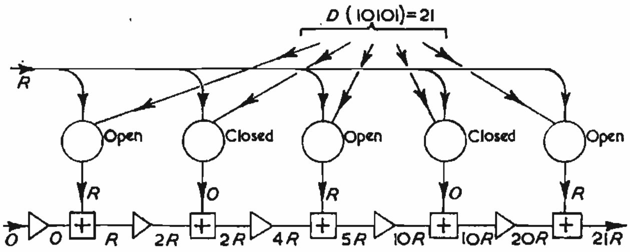

Fig. 5. Part of the multiplier chain showing multiplication of R by D (=10101)

Of these items only (1) is given by the digits of the numbers as they are taken from the main store. In the system adopted in the Manchester machine the sign convention of each factor is given by the instruction which causes it to be taken from the main store. Whether the product is to be added or subtracted is given by the instruction for the R-operation. Thus there are six kinds of instruction connected with multiplication.

1. D-operation—D signed.
2. D-operation—D unsigned.
3. R-operation—R signed—add product into accumulator.
4. R-operation—R signed—subtract product into accumulator.
5. R-operation—R unsigned—add product into accumulator.
6. R-operation—R unsigned—subtract product into accumulator.

† *In the method of multiplication described in Reference 4 the multiplicand, D, is transferred first and then the multiplier, R. In the system described here the order is reversed, but the letters D and R are still used for the first and second factors to be transferred.*

* *In what follows reference to subtraction into the accumulator will often be omitted in order to avoid repetition.*

The Basic Method of Multiplication

We have seen that there are three processes involved in binary multiplication.

1. The multiplication of R separately by each of the forty digits, d_K, of D.
2. The multiplication (or "shifting") of the resulting products by the apropriate powers of two.
3. The addition of the forty resulting numbers.

(1) is performed by applying a pulse-train representing R to the inputs of a number of gates, each of which is

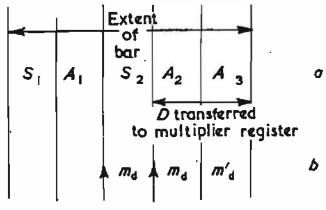

Fig. 6. Timing of D-operations

(a) Designation of beats.
(b) Lines scanned in multiplier register.
The vertical arrows show the times at which the multiplier register line selecting circuit is constrained to scan line m_d

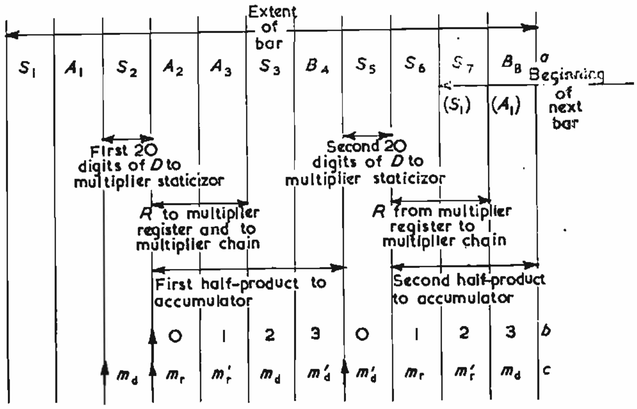

Fig. 7. Timing of R-operations

(a) Designation of beats.
(b) Lines scanned in accumulator.
(c) Lines scanned in multiplier register.
The vertical arrows show the times at which the line selecting circuits are constrained to scan particular lines

open if the corresponding digit, d_K, of D is 1. If d_K is 1 the output pulse-train will represent R; but if d_K is 0 the gate will be closed, and the output will represent 0. Thus the outputs of the gates give the products $d_K R$.

For multiplication by powers of two, use is made of the serial representation of numbers. If a pulse-train representing a number is passed through a circuit which delays it by one digit-period, then the resulting pulse-train will represent the original number shifted one place, i.e. multiplied by two. Similarly a delay of two digit-periods multiplies the number by four, and so on. Fig. 4 will make this point clear.

The additions of the shifted numbers (or partial products as they will be called) have usually been done successively by a single adding circuit[4,5,6]; but, in principle, it is possible to do them simultaneously by forty adding circuits, each adding one of the partial products, or by an intermediate method, using say twenty adding circuits to form the product in two steps. This last method is the one used in the Manchester machine. During each step R is multiplied by twenty of the digits of D to give a *half-product,* which is added into the accumulator as it is formed.

Fig. 8 shows enclosed in the broken line the arrangement of gates, delay circuits and adding circuits which form the half-products. In the first step of the R-operation the twenty least significant digits of D are recorded by twenty bi-stable trigger-circuits, which collectively form the *multiplier staticizor.* Each of the gates s_0 to s_{19} is open when the digit d_k held by a corresponding trigger-circuit is 1. The least significant digit controls gate s_0, the next least significant controls s_1, and so on.

When the twenty least significant digits of D have been set up on the trigger-circuits R is fed as a pulse-train to the inputs of the gates, so that the products of R and twenty of the digits of D appear at the outputs. These products are added together by the delay and adding circuits*. Fig. 5 shows the numbers represented by the pulse-trains appearing at the terminals of the last five adding and delay circuits when D is twenty-one. It will be seen that an output from the right-hand, or least significant gate, s_0, passes through no delays on its way to the accumulator, an output from s_1 passes through one delay, which multiplies the corresponding number by two, and so on. Thus in the formation of the first half-product, each partial product is multiplied by the correct power of two as it passes down the chain of adding circuits, or *multiplier chain* as it will be called.

The arrangement of alternate adding and delay circuits has the advantage that the number of delay circuits required is minimized, and also that the delay inherent in each adding circuit can be neutralized by a corresponding deficiency in the delay of the following delay circuit. In practice an aperiodic form of delay circuit is used, which delivers its output pulse at the beginning of a digit-period even if the input pulse occurs late in the preceding digit-period. These delay circuits must deal with numbers expressed as pulse-trains extending over more than one beat. Arrangements have therefore been made for an input in digit-period 19 of any but the last beat of a pulse-train to produce its output five digit-periods later in digit-period 0 of the next beat.

When the first half-product has been formed, the twenty most significant digits of D replace the twenty least significant digits on the multiplier staticizor, and R is again sent to the inputs of the gates to produce the second half-product.

Timing of Operations in the Multiplier

Figs. 6 and 7 give the timing of operations in the multiplier during multiplication. Fig. 6, which refers to the D-operation, shows how the new D is transferred, via gate 1 of Fig. 8, to the multiplier A_2 and A_3. The line-selecting circuit is constrained to scan line m_d in A_2; and, as has been explained, line m_d' will be scanned automatically in the next beat. The old D appears at the read output terminal, but it does not pass gate 2 which is closed. Thus D is written on the lines m_d and m_d' of the multiplier register, with the least significant half on the line m_d. During the D-operation a signal from control indicates the sign convention of D, and this is used to set a bi-stable trigger-circuit in the multiplier, which modifies the following R-operations in accordance with the sign convention of D.

Fig. 7 gives the timing of R-operations. During S_2 of each bar the line selecting circuit is constrained to scan line m_d, and the twenty least significant digits of D are read from this line and sent, via gates 2 and 3, to the multiplier staticizor. If an R-operation is to take place in the bar under consideration, the number R is sent from the main store via gate 1 during A_2 and A_3. The line selecting circuit is constrained to scan line m_r in A_2, and gate 2 is closed, so that R is recorded by lines m_r and m_r' of the multiplier register. At the same time R is sent via gate 4 to the multiplier chain, passing through the extending circuit. This circuit receives a signal from control, causing it to extend R by adding 0's at the most significant end if R

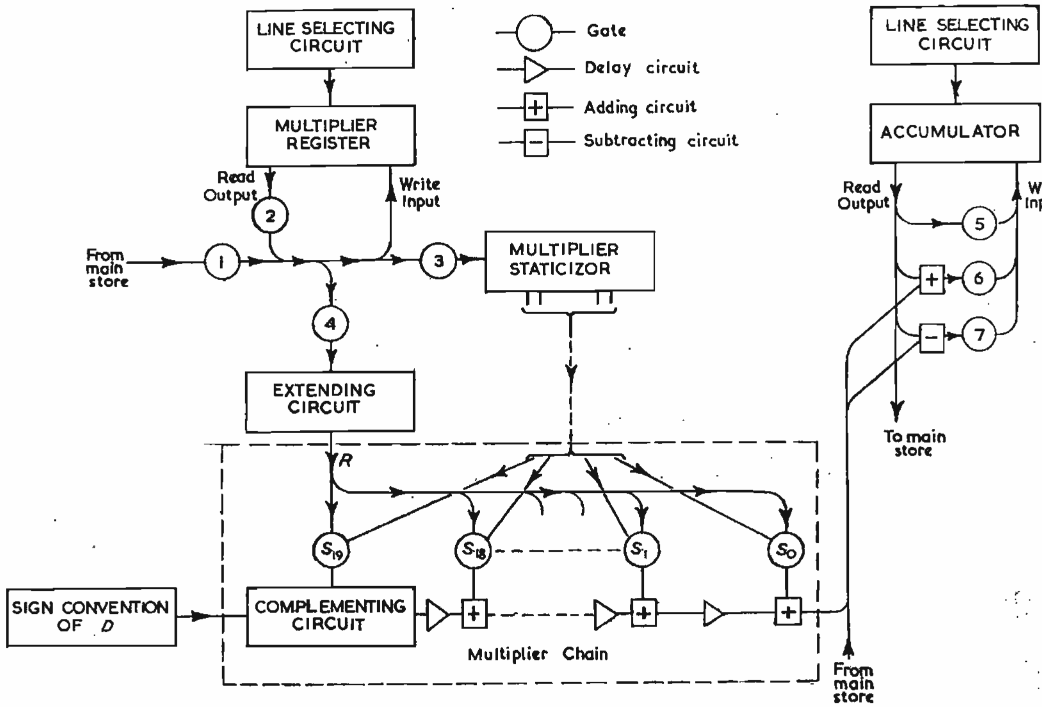

Fig. 8. Schematic diagram of multiplier and accumulator

Many details of the accumulator which do not concern multiplication are omitted

* *These adding circuits are of the type described in Section 8.2 of Reference 4.*

is unsigned, or by repeating the last digit if it is signed. The eighty-digit half-product is produced in A_2 and A_3, S_3 and B_4, and is added or subtracted into the accumulator according to the instructions received from control, which close gate 5 and open either gate 6 or gate 7. The accumulator line selecting circuit is constrained to scan line 0 in A_2 and the lines 1, 2, and 3 follow automatically in A_3, S_3, and B_4. The complementing circuit has no effect during the formation of the first half-product.

In S_5 the multiplier register line selecting circuit is constrained to scan line m_d', and the twenty most significant digits of D are read from the register. They are sent via gate 3 to the multiplier staticizor. In the next two beats, S_6 and S_7, the lines m_r and m_r' are automatically scanned. R is read out and sent through the extending circuit to the multiplier chain to form the second half-product. If D is signed, its most significant digit has the opposite sign to the remainder of the digits. This is taken account of by reversing the sign of R, after it has passed through gate s_{19} of the multiplier chain, by means of the complementing circuit*. This takes place during the formation of the second half-product if the trigger-circuit which registers the sign convention of D shows it to be signed.

The number of delay circuits between each gate of the multiplier chain and the output of the chain is correct during the formation of the first half-product; but for the second half-product there are in each case twenty too few delays. This is corrected by adding the second half-product to the sixty most significant digits of the number in the accumulator, which is equivalent to shifting the second half-product by twenty places. It will be seen from Fig. 7 that the lines 1, 2, and 3 of the accumulator, which contain the sixty most significant digits, are scanned during the formation of the second half-product without the necessity of constraining the line selecting circuit again.

Speed and Size of the Multiplier

The time taken for multiplication, using the system of multiplication which has been described, is five beats for the D-operation and nine beats for the R-operation†. A beat is 240μsec long, so that these times are 1·2msec and 2·16msec, or 3·36msec for the whole operation of extracting two numbers from the main store, multiplying them together and adding or subtracting their product into the number in the accumulator. This must be compared with the 0·96 or 1·2msec (four or five beats) required to perform the simple operations of the machine.

The size of the multiplier may be estimated from the number of valves in it, which is about 250 pentodes and 700 diodes‡ of which about 150 pentodes and 500 diodes are in the gates, adding circuits, and delay circuits of the multiplier chain. The total number of valves in the computor is approximately 1 700 pentodes and 2 300 diodes. Thus nearly a quarter of the valves of the machine are in the multiplier. This large size of the multiplier is the price paid for the low ratio of time for multiplication to time for simple operations in the Manchester machine.

Binary multiplication is an operation which consists essentially of many additions, and, as has already been pointed out, these can be done slowly by successive additions in a single adding circuit, quickly by simultaneous additions in a large number of adding circuits, or at an intermediate speed by an intermediate number of adding circuits. The size of the multipliers increases with their speed, and in the design of a computing machine a balance must be struck between speed and size. The factors which must be considered when deciding on the optimum speed of the multiplier are,

(1) the multiplication times and sizes of several possible multipliers together with their probable reliability and ease of maintenance,

(2) the time for the ordinary operations of the machine (such as addition, subtraction, and transfers of numbers from one part of the machine to another),

(3) the size of the remainder of the machine, and

(4) the proportion of multiplications to other operations in the class of problems to be solved by the machine. Most of these factors can only be estimated, and it will be appreciated that the optimum speed of the multiplier in the Manchester machine could not be exactly fixed by consideration of them. It is probable, however, that the speed of the multiplier lies within a factor of two of the optimum speed. The reliability and ease of maintenance of the multiplier have been found to compare well with those of other parts of the machine.

Summary and Conclusion

The multiplier in the computing machine which has been recently installed at Manchester University forms the product of forty-digit binary numbers, which may be signed or unsigned, by multiplying one of them first by the twenty least significant digits and then by the twenty most significant digits of the other, and then adding the two half-products so formed. A method of multiplication is used in which twenty processes of addition (or nineteen of addition and one of subtraction) proceed at the same time. The half-products are added to, or subtracted from, a number stored in the accumulator as they are formed. The complete process of multiplication and addition, or subtraction, takes place in 3·36msec.

Acknowledgments

Acknowledgments for advice and suggestions during the design of the multiplier are due to Prof. F. C. Williams and Dr. T. Kilburn of Manchester University, who also decided on the type of multiplier to be used. Further acknowledgments are due to Messrs. Ferranti for permission to publish this article.

Appendix

The Dual Nature of the Multiplier Chain

The Manchester computor is a serial machine, and the multiplier chain has therefore been regarded as a device which deals with numbers in serial form, although one of the factors (D) must be supplied in parallel form. The action of the chain is then described as the simultaneous, or parallel, addition of twenty serial numbers, d_kR.

In parallel machines[6], however, it is natural to regard the same mechanism as dealing with numbers in parallel form, although one of the factors (R) must be supplied in serial form. The action of the chain is then described as the successive, or serial addition of twenty parallel numbers, r_kD, one number being added to the number passing down the multiplier chain (or *shifting register* as it is called in a parallel machine) in each digit-period.

Thus, it may be said that, in the multiplier described in this article, a high speed of multiplication has been obtained by the use of what is in effect a parallel multiplier in a serial machine.

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* *This circuit is basically of the type described in Reference 4.*

† *The R-operation has eleven beats altogether, but two of these overlap the next bar.*

‡ *Only half the valves of the multiplier staticizor have been included in these numbers, since the same staticizor is shared between the multiplier and the magnetic drum transfer circuits.*

D.C. Relays

Some Recent Techniques and Developments

By N. E. Hyde*

A good deal of emphasis has recently been directed to the improvement of radar, radio and telecommunication components for use in the Services, and this article is intended to summarize the attention that has been, and is being given to D.C. *relay development.*

The author proposes to outline some of the more recent advances in the design of various D.C. *relays which have been developed during and subsequent to the 1939-45 war.*

This article will first mention some of the factors pertaining to the design of such relays and will go on to the development of the G.E.C. "flying lead" relay and the Siemens' miniature high-speed relay, which were completed during the war period, followed by developments which were started during the war but which have not yet been completed. Finally, mention will be made of several post-war designs such as the E.M.I. moving-iron relay and the relay developments of Walter Instruments Ltd.

SOME 30 years ago comparative tests were carried out at the British Post Office Research Laboratories upon sample relays submitted to them by each of the main relay manufacturers. The object of the tests was to enable them to standardize on a relay for general use in automatic telephone exchanges. The tests, which referred to unsealed relays, indicated the following facts:

(a) That relays mounted with the spring-sets in the horizontal plane had a greater fault liability than those with the spring-sets mounted in the vertical plane.

(b) That "buffered" springs had less fault liability than "unbuffered" springs.

(c) That double contacted springs greatly reduced the fault liability factor.

User Specification

The main circuit requirements of any relay in Service equipment may be briefly summarized as follows:

(a) It must meet a very large range of conditions affecting spring-set load.

(b) It must meet a limited range of conditions affecting operate and release currents and also of operate and release times.

(c) The adjustments once made by the manufacturer, must be definite and permanent.

These requirements may not at first sight appear too stringent, but it should be borne in mind that severe Service conditions call for satisfactory functioning over a voltage range of ± 20 per cent; a temperature range of $-40°C$ to $+100°C$; a range of air pressure of 120mm to 1 500mm of mercury; under accelerations as large as 9g; shocks of the order of 12g and vibrations of 0·005 inch at frequencies up to 100c/s; in atmospheres of 95 per cent humidity at 100°C, and conditions likely to produce electrolytic corrosion.

In addition to the stringent conditions specified above, there is another less capable of specification, which has a far-reaching effect upon the design and performance of the open construction type relay—the hazard of corrosion—which necessitates protection to metal parts. It may not at first sight be apparent that the operational efficiency of a relay is influenced by this coating, but it has been found that for optimum results, the magnetic iron parts should be nickel-plated on copper with a chromium flash added to prevent corrosion. This plating is not necessary in the sealed types, although it is important that their piece parts should be well preserved prior to and during final assembly and if kept in store before sealing should be suitably protected against damp or other attacking agents such as chemical fumes.

Factors Pertaining to Relay Design

Armature Stiction

Armature stiction due to residual magnetism in the iron circuit as a result of repeated operation is normally overcome by facing the pole piece or armature, or both, with some non-magnetic coating or alternatively by means of a non-ferrous screw threaded through the armature, which is adjusted so that under "operate" conditions a minute—or otherwise if desired—air-gap exists between the armature and the polepiece and direct adhesion is then avoided. The latter method is usually adopted as the coating method may in itself cause mechanical adhesion of the two faces under certain conditions.

Timing of Relay

The most common method of altering the time-constant of a relay is by the use of copper "slugs" or "sleeves." These act as a single-turn secondary winding having a large time-constant. On removal of the coil energizing current the ampere-turns in the coil are temporarily transferred to the slug or sleeve and the armature remains attracted until the stored energy has slowly declined to the normal release value of the relay.

Great flexibility of operation is obtained by these devices as a slug fitted to the front end of the core—that end adjacent to the armature—gives a slow to operate and slow to release characteristic while a slug fitted at the rear end of the core gives a quick to operate and slow to release feature.

A range of some 10-300 milliseconds time lag can be obtained on Service relays of the K3000 type fitted with these devices. Figures for the miniature relays mentioned later are not yet available. It will be apparent that spring-set or armature load plays an important function in the timing, and that heavy loads will limit the range considerably. The residual air-gap is also an important factor in determining the release time of a delay, but with a well designed and efficient magnetic circuit a longer air-gap is possible and greater stability of release times obtainable.

There are, of course, other methods that can be adopted to produce release delays in a relay, and the following

* *Formerly Admiralty Signal and Radar Establishment.*

are a few of the more common:

(a) The short-circuiting of a secondary low resistance winding—comparable with the slug or sleeve method described above.

(b) The connecting of a rectifier or resistor in parallel with the relay coil.

(c) The connecting of a large capacitor in parallel with the relay coil or alternatively discharging such a capacitor through a secondary winding on the relay.

In considering a decrease in operating times, the inductance of the coil should be reduced, and a partly wound coil is therefore better than a fully wound one. For this circuit condition the operating current should be about 0·75 of the final current for optimum results.

Contact Springs

Another design problem associated with relays is the choice of material for the manufacture of the small flat centilever springs which carry the contacts. The springs are generally blanked from thin sheet or strip and are frequently formed into rather intricate shapes in punch presses. Care must be taken to see that the grain orientation is correct for the material being used.

These parts often carry currents of the order of 5 amperes at about 200 volts; contact is sometimes made between two base metal springs, but more frequently between precious metal contacts riveted to the springs, or alloys welded to them. The material used, therefore, must combine high elasticity and fatigue properties with good electrical conductivity and weld-ability and be sufficiently ductile to permit forming without difficulty.

Generally speaking, the contact spring material must be non-magnetic, corrosion resistant and in some cases resistant to creep or drift under continuously applied loads.

High carbon steels are frequently unsuitable for use as springs in communication equipment because they lack adequate corrosion resistance and are magnetic.

The two materials most widely used are phosphor bronze and nickel-silver alloys. However, since the best combination of spring properties is obtained in these materials by cold rolling, the forming impairs the temper at which they should be used.

The material beryllium copper is a corrosion resisting, copper base alloy which can be formed in the soft annealed state and heat treated afterwards to obtain the spring characteristics required. For these reasons beryllium copper contact springs are frequently used, especially for miniature components.

Pressures in Contact Springs

If a curve for such cantilever springs be obtained by plotting "pressure build up in the spring" against "armature displacement" and superimposed upon this a similar curve obtained by plotting "magnetic force" against "armature displacement" then the minimum "operate" ampere-turns for the relay can be obtained. It is frequently found that it may not be the initial nor the final pressure which determines the "fully operate" current; further free springs (unbuffered) show a more gradual increase of pressure than buffered springs, the latter having a steeper movement-pressure characteristic.

The tendency towards the use of buffered springs as exemplified in the K3000 type relay stresses the need for the above curves. A buffered spring can be adjusted to closer tolerances than free springs and dispenses with the tedious current adjustment which the latter entails. In miniature relays owing to the short springs buffering is not always practicable, but it is possible to use a combination of non-flexible and flexible springs which dispenses with the need. Such combinations have been used for switching as much as 10 amperes at a potential of 12 volts giving a life of several thousand operations in air at 85°C. To succeed in handling such currents, it is imperative to have bounce-free operation and to choose suitable contact material of correct size, volume, contact resistance, etc.

Contacts and Contact Materials

Substantial advance is thought to be possible if better contact materials were available. At present the method of assessing the relative merits of various contact materials is to produce a large number of alloys and submit them to trials in actual components under various conditions.

The number of variables in each experiment together with the large number of different contact materials available provide such a number of combinations to be dealt with that a rough estimate recently made indicates that many years' experimenting on normal lines would be required to solve the problem on statistical experimental lines.

A few physicists are engaged on fundamental investigation into the problems of material transfer due to arcing and the formation of molten bridges. In the former, metal transfer is nearly always in the same direction—the negative electrode or contact will build up and the positive will be pitted. In the latter, however, when a molten bridge is formed as a contact opens, the temperature of the bridge rises until the boiling point of the material is reached when it explodes and destroys the bridge. It might be expected that with similar materials the hottest part of the bridge

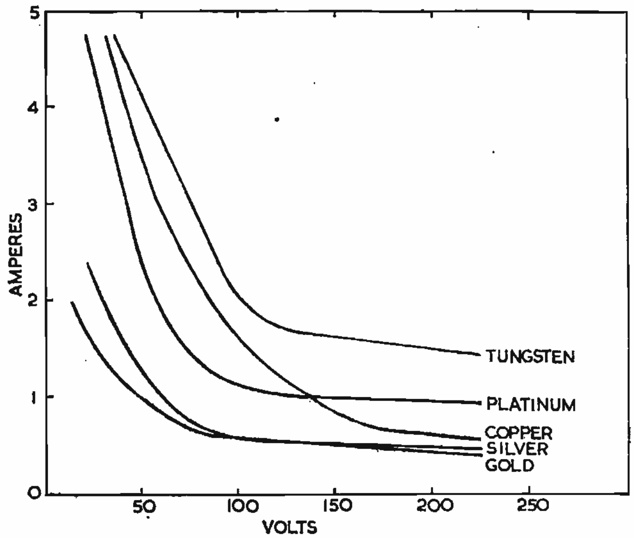

Fig. 1. Limiting arcing-current/voltage curves for silver, gold, platinum, copper and tungsten

would be at its centre; this is not, however, the case, as the Thomson effect (i.e. heat transfer due to a current flow) causes the hottest region to be displaced in one direction or another dependent upon the Thomson coefficient of the material. Other factors also enter into the direction of material transfer.

The more common contact materials used for relays are silver for light-duty work, and platinum for medium-duty work and for applications in which very low contact resistance and freedom from tarnish is imperative. Large silver contacts are extremely useful for heavy duty work up to 5 amperes at 230 volts D.C. and A.C. (R.M.S.) in air at atmospheric pressure, but although the oxides of silver are conducting, the sulphides are not and adequate contact pressure must be provided. The silver molybdenum alloys sometimes used for work requiring a repetitive number of operations at fairly heavy loads are unfortunately extremely prone to heavy corrosion even in Britain, and so frequently produce very high contact resistance which potentials of several hundred volts cannot break down. The oxide layer which forms is also difficult to remove manually.

Generally speaking, the maximum current which can be interrupted by a pair of contacts is governed by the resistance of the contact material to arcing, and this may take the form of light-duty wear or heavy-duty wear. It is found that for a given contact material there is a limiting current which can be interrupted at each voltage between about 20 and 200 volts without drawing an arc. Below these values the electrical wear is negligible and is due to bombardment of the positive contact by free electrons from the negative contact. This forms the light-duty aspect. Approximate limiting arcing currents for gold, silver, platinum, and tungsten being 0·4, 0·45, 0·9 and 1·4 amperes respectively at approximately 200 volts. (See Fig. 1.)

When these critical values are exceeded, arcing results and electrical wear—now due to bombardment of ionized particles—becomes more rapid. This condition constitutes the heavy-duty case.

Thermal conductivity and capacity of the contact material are important aspects to be considered when choosing a suitable material for a given application where arcing is present. The heat produced by the arc must be dissipated quickly to prevent the temperature of the contact faces from rising to a level at which there is excessive electrical wear or even welding. In selecting a contact material it is therefore necessary to assess the relative importance of the two opposing effects, the one due to ionic bombardment which is intimately associated with the cohesive properties of the material and the other

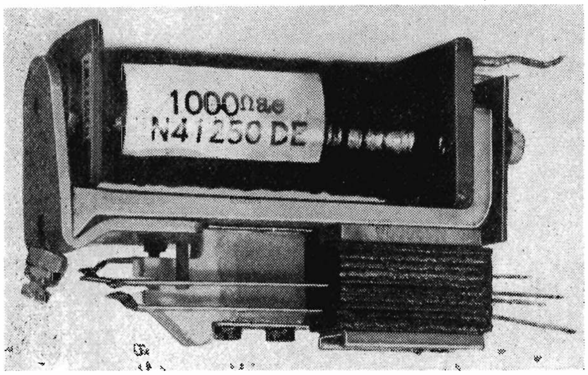

Fig. 2. The type K3000 relay

the rise of temperature which is associated with the thermal conductivity of the material.

The contacting problem although of great interest in all its aspects is too involved for further discussion in an article of this nature and the reader is referred to such literature as Radnor Holm[1] for the fundamental approach to the subject and to Dr. L. B. Hunt[2] for the application or engineering aspect.

Relay Development During the War

A survey of early field reports from various sources showed that the vacuum-impregnating technique as applied to coils does not give satisfactory insulation against humid atmospheres; this necessitated an urgent short-term solution, because in 1941 it was decided that all relays used in a certain naval radar set must embody an improved tropical finish. As a result of this requirement Messrs. Ericssons Telephones Ltd., of Beeston, developed a special process of hot wet dipping in oleo-resinous varnish containing an antifungicide. This technique gave remarkably good insulating properties under conditions of high humidity and attack by fungi, and in addition met the full requirements of the Interservice Specification R.C.S.161.

Relays produced by this new technique were submitted to tropical tests, and after 10 complete and consecutive cycles of K110 specification insulation tests showed several thousand megohms insulation on the spring-sets and over 10 megohms on the coils. This, although not considered the final word, was a considerable step forward and it was decided to apply the technique to the P.O.3000 type relays which were the Services standard relays. This modification and certain improvements in spring tensions and armature fixing resulted in the present tropical version known as the K3000 relay. This relay is depicted in Fig. 2.

Later war-time requirements of the fighting Services were for components of small size, and high performance. Miniaturization and hermetic sealing of relays therefore became one of the many items of development undertaken by the Interservice Miniature Components Sub-Committee (I.S.M.C.S-C.). It was decided by this committee that at that time relay requirements fell into two main groups: firstly, the development of a miniature relay to replace, as far as possible, the existing Service standard K3000 type

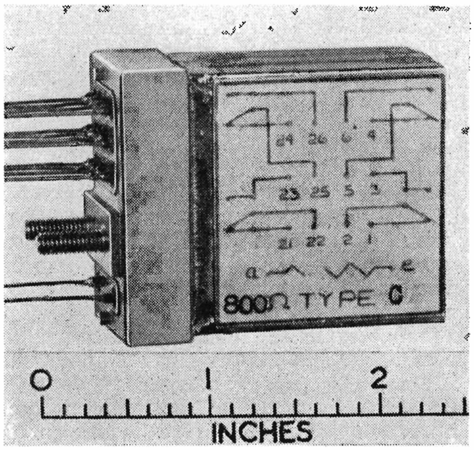

Fig. 3. G.E.C. flying-lead sealed relay

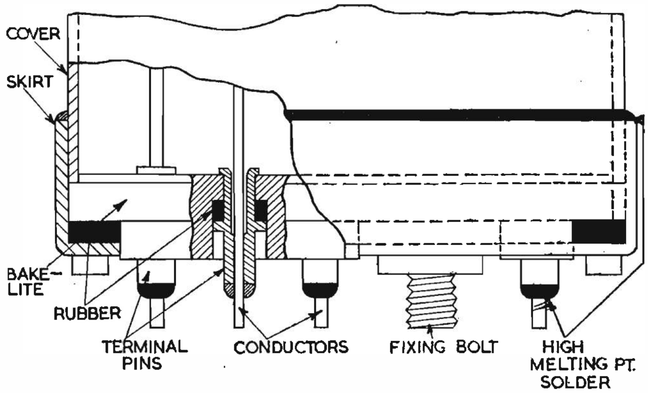

Fig. 4. Sealing method of the G.E.C. relay

relay for general purpose work, and secondly to develop a miniature high-speed relay to replace the existing Siemens high-speed relay.

Sealed Relays

G.E.C. NORMAL AND HEAVY DUTY RELAYS

It was perhaps unfortunate that at that time an urgent requirement existed at one of the Service establishments for a large quantity of miniature general purpose relays for operations scheduled in the Far East theatre of war. This urgent commitment influenced the committee in accepting the General Electric Company's development of the 12 inch flying-lead sealed relay shown in Fig. 3. This has subsequently proved to be somewhat inconvenient in anything but a miniature set, or where inter-component wiring lengths are less than 12 inches. Another serious objection to this relay is that the conductors are liable to break off easily at the relay tag. Nevertheless this was the only sealed relay available to fill the breach and, as an interim measure, a small moulded terminal block was developed to overcome both of the above objections.

METHOD OF CONSTRUCTION OF FLYING LEAD TYPE

The illustration, Fig. 4, of the sealed relay under discussion shows the sealing method decided upon by the I.S.M.C.S-C. for the flying-lead relay.

The main seal is obtained by compressing a rubber gasket between a bakelite terminal board and the spun-over metal case, while each terminal pin is sealed by individual rubber gaskets as illustrated. The conductors, after passing through the tubular terminal pins, are hard soldered to ensure an airtight joint, the flying leads being insulated by suitable tropical grade sleeving when the unit is wired into an equipment.

The relay itself has a novel armature fixing and a moulded bakelite buffer block attached to an extension of the armature which actuates the moving springs of the spring-set so dispensing with the lifting pins and bushes usually used on relays of similar construction. The armature is fixed to two 3/36 inch wide hinge springs of beryllium copper clamped between the yoke and the spring-set on one end and riveted to the armature at the other end. The moving spring is tensioned down upon a spacing piece. The clearances with an armature movement of approximately 0·025 inch are adequate by virtue of a 3 : 1 mechanical advantage.

The limitations in the design of this relay constitute some of its main weaknesses. The coil assembly is restricted to a single winding, and copper slugs cannot be fitted to produce alternative operate and release timing characteristics. The relay by virtue of the materials used in its construction is only suitable for use in ambient temperatures of 85°C maximum and it is therefore only a "Category B" component.

The organic materials used in its construction produce free organic vapours in the sealed container which permit carbonization in the presence of a contact spark. The coil dissipation is so limited that, at high temperatures, the circuit factor of safety must be reduced, so restricting the circuit applications and the margin of safety to ensure satisfactory operation.

SIEMENS MINIATURE HIGH-SPEED HERMETICALLY-SEALED RELAY

The other miniature sealed relay developed during the war under the auspices of I.S.M.C.S-C. was the Siemens high-speed relay depicted in Fig. 5. This relay, the outcome of miniaturizing and sealing the existing high-speed relay designed by the same firm prior to the war, is sealed in a similar manner to the G.E.C. relay previously described except that instead of using individual rubber gaskets around each conductor, a single gasket, pierced in the appropriate places, is used. The spinning over of the rectangular section lid to complete the seal proved to be difficult, but the difficulty was eventually overcome by re-designing the rubber gasket and controlling the spinning pressures to close limits. It will be appreciated that both methods of sealing depend for their success upon the sandwiching under pressure of rubber between two pieces of organic material.

Life tests on this relay with full load of 2 amperes at 24 volts D.C. and A.C. R.M.S. (non-inductive load) have been carried out to ascertain the effect of sparking in an atmosphere which, although initally dry air at atmospheric pressure, becomes polluted with organic vapours derived from synthetic insulating materials from which the relay is constructed. A life of several million operations is possible provided sparking does not ocur, but this life is rapidly decreased in the presence of a spark. The contact material is platinum.

It will be noticed that the moulded base is marked to enable external wiring to the relay to be carried out in accordance with the diagram of connexions printed on one of the two larger faces of the cover.

This relay is frequently used for keying purposes and is slightly superior in performance to the large unsealed high-speed relay from which it is derived, having less distortion and less bounce. Also, the operating time is from 0·5 to 1·0 milliseconds less, being about 2 milliseconds.

It is intended that this miniature sealed high-speed relay shall in the future supersede the major high-speed relay in the great majority of Service applications. Recently a holder has been designed to enable this relay to be plugged into the chassis.

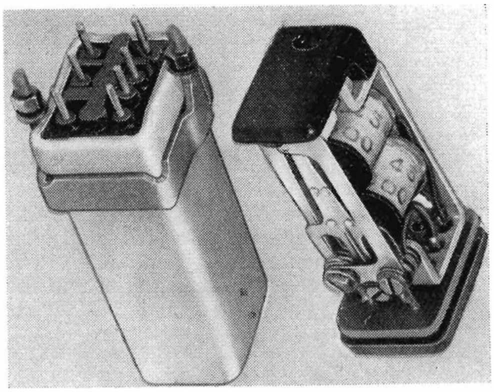

Fig. 5. Siemens high-speed relay

Post-War Position

Early in 1946 only the two sealed relays referred to above had actually been tooled up by the respective manufacturers and put into production. Type Approval has been given by the Radio Components Standardization Committee on behalf of the Services, the former as a "Category B" (40/85)* component, the latter as a "Category A" (40/100)* component.

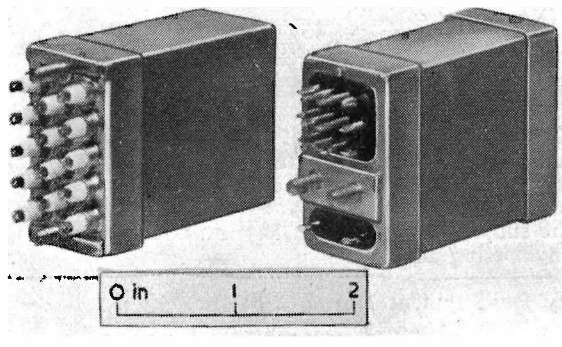

Fig. 6. G.E.C. rigid lead relay

G.E.C. NORMAL AND HEAVY DUTY RELAYS (RIGID LEADS)

As the result of a long-term contract the flying-lead method of sealing has been superseded by two other methods, each incorporating short rigid conductor leads. One method, Fig. 6(a), is to use individual K.L.G. ceramic seals soldered into the base, the other method, Fig. 6(b), is to adopt the rubber sandwich technique used on the Siemens sealed relay already described. The former method is far more expensive than the latter and both pass the inter-Service specification. It has yet to be determined

* *B(40/85) is a temperature category indicating −40°C +85°C ambient working temperature limits. A(40/100) being −40°C +100°C.*

which of these two methods of sealing should be standardized for Service use.

Present Day Position

The Services require the relay of the future to give the facilities and the sensitivity obtained from the present standard K3000 type relay, and in addition be miniature, hermetically sealed and capable of withstanding the most severe conditions of arctic and tropic exposures. Also, it has been felt that it is no use standardizing on the relay of the future which only just meets existing interservice specifications, as in all probability more stringent tests would have eventually to be met. All the types previously described have an upper temperature limit of 100°C ambient and, allowing about 20°C or 30°C rise with full wattage loading on the coils, plus increase in temperature due to the springs carrying full load, the materials used, i.e. Bakelite, Neoprene, Tufnol and Polythene, are all liable to either flow or shrinkage. This, coupled with the liberation of hydrocarbon vapours and consequent carbonization at the contact when sparking is present, have suggested an entirely new approach to the problem.

Previous designs all appear to have been evolved from the orthodox magnetic circuit as displayed by the K3000 type relay, the reduction in linear dimensions and some

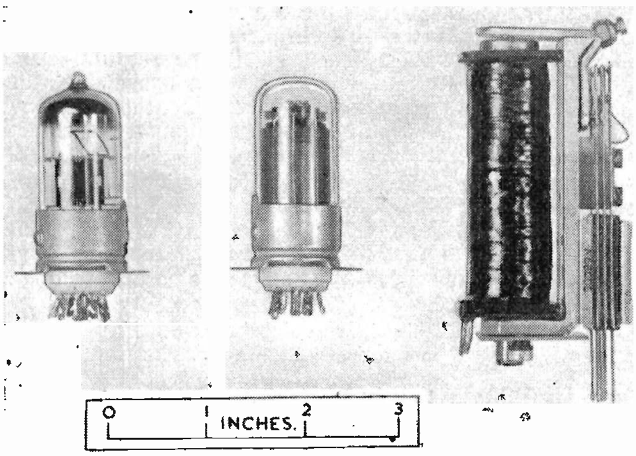

Fig. 7. Minislave relay (centre) compared with a CV455 valve and a type K3000 relay

ingenious design features being the only approach to the miniaturization problem. The temperature problem has not been faced at all, with the result that many of the relays cannot be used in "Category A" (100°C) because the maximum wattage dissipation from the coil is limited to the temperature at which the materials of the relay deteriorate.

It was decided therefore that the relay must be constructed of inorganic materials throughout, that the magnetic circuit must be improved, and that the relay should be hermetically sealed in a pressurized atmosphere of some inert gas or mixture of inert gases. The foundation of an efficient relay lies in the perfection of its magnetic system and friction-free operation. These points, therefore, had to be investigated.

Walter Instruments 2-changeover Sealed Relays ("Minislave")

In order to achieve a relay of smaller size than the usual telephone type without loss of mechanical or electrical efficiency it is not sufficient to be satisfied with reducing the linear dimensions of the orthodox pivoted armature or bell-crank-lever type relays. The problem must be tackled from fundamental principles and if necessary a completely new design evolved.

This is in fact what Walter Instruments Ltd. of Wimbledon have accomplished.

One design of theirs, the small 2-changeover relay (compared in Fig. 7 with a CV455 valve and a K3000 type relay) is of cylindrical shape, having an armature with a piston-like movement. Attached to the armature plunger is a transverse insulated rod which actuates the contacts. The magnetic circuit is of pot-type construction and the whole relay is sealed up using normal miniature valve technique.

It will be seen from the sectional drawing (Fig. 8) that the electromagnet is an open-ended cylindrical pot, into which the energizing windings are fitted around a central core. The armature is a plunger movable axially to the magnet structure. The central core is made shorter than the magnet plunger so that the latter can be driven into the operating coil when it is energized. The insulated transverse operating arm rides between the upper and lower springs of the two changeover contact assemblies.

Another unusual feature of this relay is that the centre spring of the changeover combination is fixed and rigid.

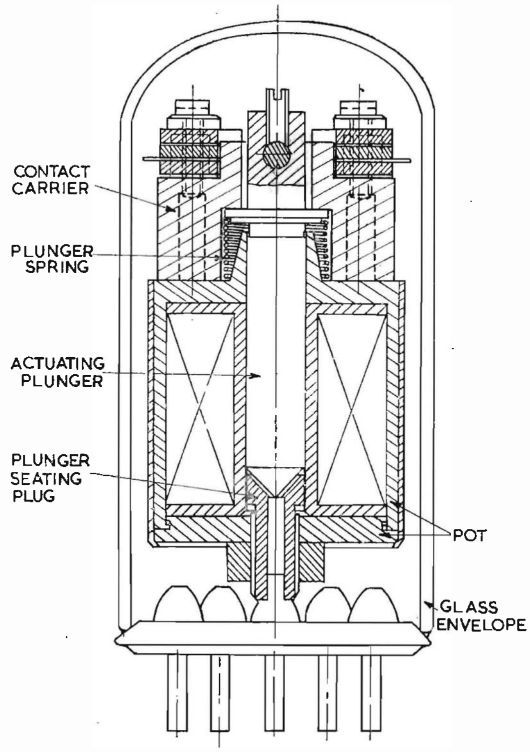

Fig. 8. Cross-section of Minislave relay

When the relay operates the upper springs assist the armature movement and when the relay releases the lower springs assist its return. The position of the contact operating rod damps vibrations in the cantilever moving springs and so reduces bounce considerably.

The relay by virtue of its cylindrical construction lends itself to the sealing techniques used for such miniature valves as the popular CV138 type. The only divergence is that the glass envelope cannot be fused to the glass button, due to the high temperature involved in fusing glass. Instead, the button, which has a chamfered inner edge is silver-soldered to the edge of the glass envelope.

The abutting edges are metalized with the new Johnson Matthey & Co. Ltd. silver pastes X351 and X353. These pastes have been proved to give vacuum-tight joints, so permitting the relay to be hermetically sealed in an atmosphere of inert gas or mixture of inert gases if desired.

In a special design made by this firm all internal parts are made of inorganic materials and the mechanical tolerances are such that the relay will work in an ambient temperature of 150°C. Their standard component is, however, rated for 100°C maximum ambient temperature working and this type, therefore, uses more conventional moulding and insulating materials. The relay plugs into the standard 9-pin miniature valve holder.

Two larger relays using the same magnetic construction have also been developed by Walter Instruments. One of these, shown in Fig. 9, is single-ended and uses solid silver shorting bars and silver contacts. It provides for 4-changeover (C) or 4 make (M) or break (B) contacts in both light and heavy duty construction with make-before-break (K) contact action as an alternative to the changeover contacts in the light duty case.

The other relay is a similar relay with 6-changeover contacts and has a 20-pin base and holder. The method of sealing is very similar to that used for the single ended 2-changeover relay described above.

Comparison of the magnetic efficiencies of the K3000 relay with those of an orthodox relay with reduced linear dimensions and with the Walter Instruments relays have been made by adopting the ampere-turns/pull relationship measured at the centre of the armature, each relay being fully saturated before each " operate " ampere-turns reading was taken. These curves, together with those of watts/pull, indicate that all three designs give similar performance except that at a 1 000 gram load the iron circuit of the G.E.C. miniature relay becomes saturated. The other relays both lift 2 000 grams without saturation. Needless to say, in this comparison all the armature travels (by calculation) were referred to one dimension. The operating time for the 2-changeover relay is of the order of 5 milliseconds and that of the 4- and 6-changeover relays of the order of 10 milliseconds.

Table 1 gives a list of the 2-changeover contact relays mentioned under this section with the operating currents, voltage and coil resistance, together with the contact rating and the firm's reference numbers.

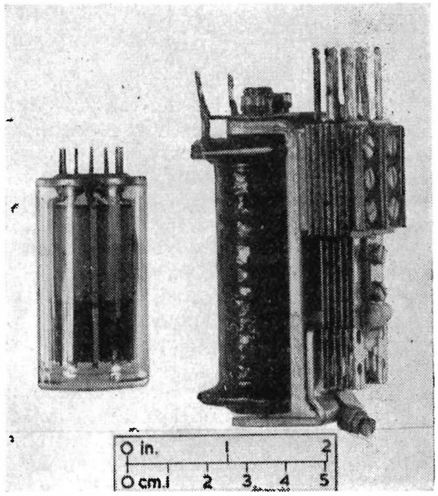

Fig. 9. A Walter Instruments relay compared with a type K3000

Polarized Relays

During the war the most sensitive small polarized relay in production in Britain for telegraph use was the Carpenter type 3 relay which was then of inestimable value in filling the breach. For many Service applications it is however too large, difficult to adjust accurately, has only one changeover contact and is unsatisfactory under tropical conditions. The ever increasing demand for small sealed, polarized relays led to the development of the single-changeover Carpenter type 5, and the Shipton and the Ericsson 2-changeover polarized relays.

The Carpenter and the Shipton relays each have a half-bridge magnetic circuit, the Ericsson relay has a full-bridge circuit. The half-bridge suffers from shunting of the operating flux by the polarizing system and special steps have to be taken to introduce high reluctances into the polarizing system to reduce this effect. In the case of the first mentioned relay two magnets are used in a way conducive to magnet deterioration, but in the Ericsson relay the two magnets used are arranged consequently and deterioration does not take place. In the Shipton relay, also, in which only one magnet is used, a symmetry of polarizing gap reluctances cannot take place, therefore any changes in these gaps only affect the amount of contact pressure and not their symmetry.

Apart from magnetic circuit considerations, relays of this type, in which finely balanced systems are created in order that high speed and great sensitivity to injected current are possible, the problems of mechanical and thermal stability are accentuated and become major design problems.

The Shipton polarized relay is shown in Fig. 10, the Carpenter Type 5 in Fig. 11 and the Ericsson in Fig. 12.

The E.M.I. Balanced Armature Relay

The E.M.I. moving-coil relay was evolved as the result of an exploratory contract, the main object of which was to determine whether or not there is any reason why a relay with very small dimensions should not handle a reasonable load.

The target specification (besides including the general Service requirements detailed in R.C.S.11 and R.C.S.165) stated maximum dimensions as $\frac{1}{4}$in. by $\frac{1}{4}$in. by $\frac{1}{4}$in., i.e. 1/64 cubic inch in volume; ambient temperature category

TABLE 1

OPERATING CONDITIONS OF 2-CHANGEOVER RELAYS TARGET CLASSIFICATION : R.C.S.11 AS CATEGORY A (40/100) CLASS H.1

(A)	(B)	(C)	(D)	(E)	(F)	(G)
NOMINAL VOLTAGE	STANDARD VOLTAGE LIMITS	COIL RESISTANCE (OHMS)	MINIMUM CIRCUIT VOLTAGE	MINIMUM CIRCUIT CURRENT (mA)	CONTACT RATING (LIGHT-DUTY)	MANUFACTURERS CODE
1·3	1·1—1·5	$2\pm0{\cdot}25$	0·9	400	300 volts D.C. or A.C. 100 mA or 24 volts D.C. 1 ampere	A3500/2
6·0	4·8—7·2	10 ± 2	4	330		A3500/10
12·0	9·6—14·4	39 ± 8	8	270		A3500/39
24·0	19·2—28·8	200 ± 20	16	72·5		A3500/200
48·0	38·4—57·6	1000 ± 5	30	30		A3500/1000

NOTES : (1) Sealing. All types are sealed.
(2) Resistance Values (Col. C). Apply at 15°C and will be increased by about 50 per cent at 100°C.
(3) Minimum Circuit Voltage (Col. D). Provides adequate safety margins under all conditions up to 100°C.
(4) Minimum Circuit Current Col. E). Provides adequate factor of safety. It should be calculated for adverse conditions of voltage, resistance and working temperature.
(5) Contact Rating (Col. F). The D.C. loads assume adequate spark quenching.

A, i.e. -40°C to $+100^{\circ}$C; spring-set working voltage 350 volts D.C. or A.C. and the single make or break contact to handle approximately 35 watts, i.e. 100mA at 350 volts D.C. non-inductive load.

The firm, after investigating methods of driving such as the piezo-electric effect, the magnetic control of gaseous discharge, the magneto-striction effect, the electro-magnetic moving-iron and moving-coil systems and the Johnson-Rahbek effect found the moving-iron system to be the most efficient of all the systems investigated, but a balanced armature system was finally adopted as it permitted a more adjustable controlling mechanism.

Of course, a departure from the more orthodox contact pressures and contact spacing was necessary and experi-

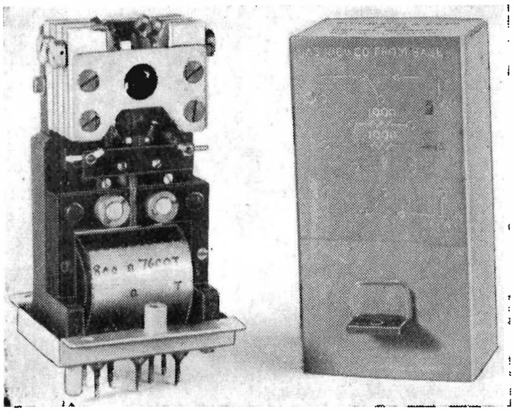

Fig. 10. Shipton polarized relay

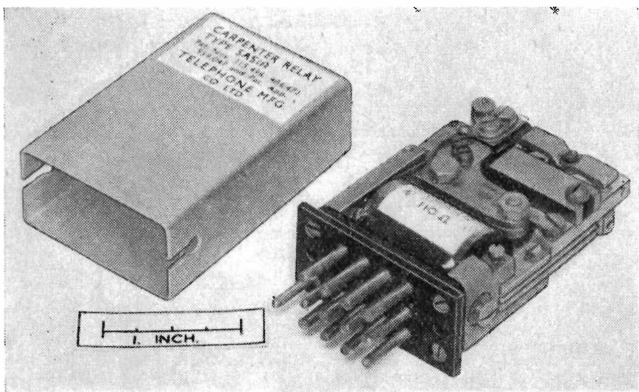

Fig. 11. Carpenter type S relay

ment showed that under sealed conditions contact pressures of 4 grammes (minimum) for platinum and silver contacts gave reliable contacts up to 10 million operating cycles. Contact gaps of the order of 0·005in. were satisfactory for 350 volts working.

As working ambient temperatures of 100°C are envisaged, the temperature rise of the windings would bring the wire temperature up to approximately 150°C.

To meet the ambient temperature condition of 100°C plus an estimated temperature rise of 50°C when the coil of the relay is continuously operated it was proved that enamel-covered coil wire could not be used and that anodized aluminium wire is superior. The space factor of anodized aluminium wire more than compensates for the higher resistivity figure of aluminium over copper.

It is difficult to soft solder to aluminium oxide wire because the elimination of the oxide film is not possible with normal fluxes. Some fluxes which have been used release a nascent element which stimulates a short violent reaction with the oxide, after which, however, the oxide film reforms immediately.

By using the ultrasonic soldering technique a positive soldered metal-to-metal joint is possible. When a liquid is subjected to ultrasonic vibration or stimulation, the phenomenon of cavitation occurs. The pressure caused by cavitation disrupts the oxide surface, destroys it and so cleans the surface of the aluminium wire. By using molten tin as a liquid medium, a flow of metal is obtained and a good soldered joint is achieved.

An experimental relay with dimensions as already stated

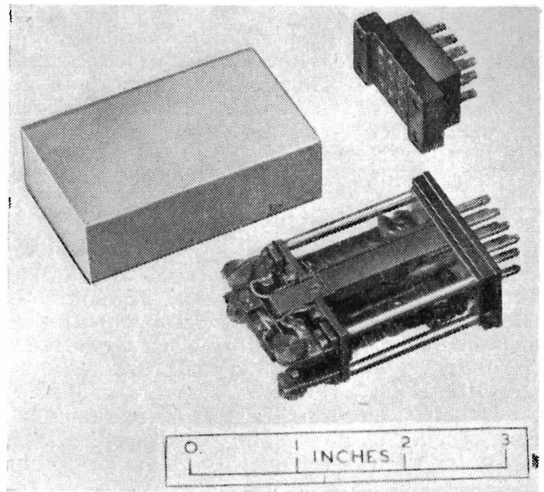

Fig. 12. Ericsson polarized relay

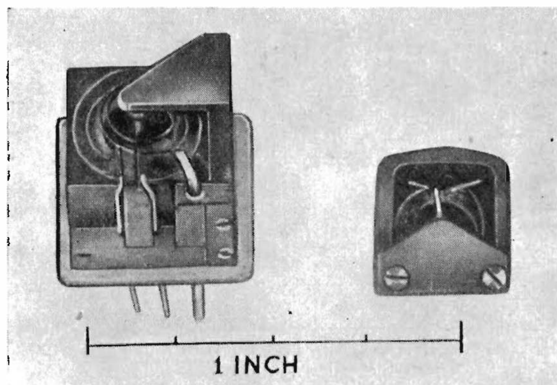

Fig. 13. E.M.I. experimental balanced armature relays

is shown in Fig. 13 together with a larger model of $\frac{1}{2}$in. by $\frac{1}{2}$in. by $\frac{1}{2}$in. The latter relay was scheduled to go into production as a Class H1, Category A component early in 1952. The reason for increasing the volume to $\frac{1}{8}$ cubic inch is to permit adjustment and buffering of the springs, and satisfactory anchorage of the fine coil leads. Also, a greater degree of safety above the working voltage can be obtained.

Acknowledgments

The author is indebted to Messrs. Ericsson Telephones Ltd., Walter Instruments Ltd., E. Shipton & Co. and Electric & Musical Industries Ltd. for their kind assistance in providing information and in some instances photographs for illustrating the article.

Acknowledgment is also due to the Admiralty for permission to publish this article.

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Corona Discharge Tubes for Voltage Stabilization

By E. E. Shelton* and F. Wade†

CORONA stabilizer tubes are low current, constant voltage devices. Before dealing with their characteristics and manufacture it will be useful first to look briefly at the general current versus voltage characteristic curve observed during the conduction of electricity through a gas at a pressure of the order of a few millimetres of mercury. Fig. 1 shows such a curve, with the current scale expanded towards zero as a convenient way of showing the very small currents in the region OABCD. In a tube with two electrodes, say parallel planes or concentric cylinders, situated in a low intensity of weakly ionizing radiation (as is always the case with the natural background of radioactivity and cosmic radiation) then as the potential difference between the electrodes is slowly increased from zero, we find that more and more of the ions generated between the electrodes are collected (OA) until saturation is reached. Further increase of voltage produces no new effects (B) until gas multiplication starts (C). With increasing voltage, ionization by collision increases (CD), until a point (E) is reached where the discharge is unstable. If the voltage is increased beyond

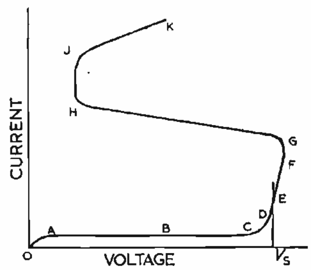

Fig. 1. General current/voltage characteristic for conduction of electricity through a gas

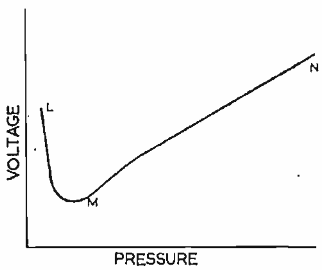

Fig. 2. General voltage/pressure characteristic

this point a continuous discharge commences. This is called a corona discharge. The current is of the order of a few microamperes, and in the dark a faint glow can be seen near the anode. This voltage is usually referred to as the "sparking" voltage or "striking" voltage, but it will be referred to here as the stabilizing voltage (V_s) since this is the region in which corona stabilizers operate.

If the two-electrode tube is now operated with a series resistor of adequately high value, and the current through the tube is increased, it will be found that there is a region (EF) over which the voltage across the tube increases only slightly although the current is increased by a factor of 20 or even more. Next there is a region (FG) where the voltage remains constant while the current increases, after which the voltage across the tube decreases as the current increases (GH), i.e., the incremental resistance of the tube becomes negative, and if the series resistance is low enough, the mode of operation passes suddenly into that of the "glow" discharge, when a bright glow appears on the cathode surface. Over the region HJ this glow spreads over a larger area of the cathode as the current increases. This is the region in which the more familiar cathode-glow stabilizers work. Finally, after the cathode is completely covered with the cathode glow, further increase in current again produces an increase in voltage across the tube.

It is well known that the stabilizing voltage (V_s) is dependent on both the field between the electrodes, and the gas pressure; the general relation between V_s and pressure is shown in Fig. 2, and we shall examine this relationship in more detail later, but only over the region marked MN.

The work reported here was undertaken because a need had arisen for stabilizing the voltage supply to low voltage halogen quenched Geiger-Muller counter tubes[1]. The statement of requirements specified that the output voltage should be approximately 400 volts and should be stable over a wide range of input voltage; the current consumption should be as low as possible and the external dimensions should be as small as practicable. Work already published had been confined to tubes having stabilized outputs of 1 000 volts or more[2] and a preliminary survey

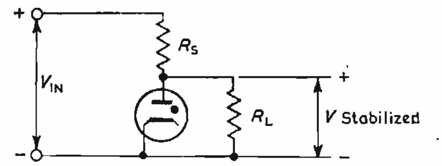

Fig. 3. Basic circuit for stabilizer or regulator tube

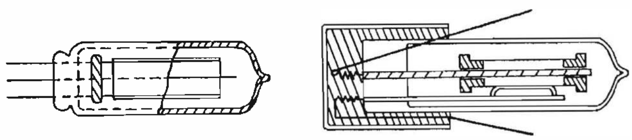

Fig. 4. Construction of experimental corona discharge tubes

in the same voltage range had also been made by Jaques[3] at A.E.R.E. It was decided to limit the work to electrodes consisting of concentric cylinders with the central cylinder or wire used as the anode.

The Regulating Circuit

Circuit design considerations have been dealt with in considerable detail in a recent article by Lichtman[4] but we shall consider only the simplest statement of the circuit and tube relationship. The basic circuit is shown in Fig. 3. The slope of the voltage versus current curve for the tube from the commencement of the corona discharge to some chosen current within the allowable range, is very approximately constant; this incremental resistance we denote by R_c. The external series resistance is R_s. It can be seen by inspection, that when R_1 the load resistor is infinite, the ratio of voltage variation on the output to the voltage variation on the input is:—

$$s = \frac{\Delta V_s}{\Delta V_{in}} = \frac{R_c}{R_c + R_s}$$

This factor is referred to as the stabilization ratio.

It is obviously desirable for s to be small, so R_c must

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* *Nucleonic and Radiological Developments, Ltd.*
† *Atomic Energy Research Establishment.*

be as small as possible, and R_s as large as possible. In some applications the parallel load R_1 may be appreciable, in which case as the value of R_1 decreases or that of R_s increases, the applied voltage must be made greater in order for the voltage on the tube to reach the striking potential V_s; the disadvantage of this is self-evident, and clearly R_1 should be kept as large as possible.

Tube Construction and Processing

Fig. 4 shows two constructions used in experimental tubes. In Fig. 4(a) a tubular nickel cathode is shown mounted concentrically about a nickel anode wire. The two cathode support wires and the anode wire are held in position by a glass bead, and are sealed into a glass bulb. The tube in Fig. 4(b) employs a slightly different method of construction; the anode wire is held in position with the aid of a ceramic insulator at each end of the cathode. A single wire is welded to the cathode, the assembly then being sealed into a glass bulb. When processing is complete, a cover filled with a suitable wax is placed over the seal for protection and to enable the flexible leads to be anchored firmly at the seal.

In the development work, many types of experimental tubes were made, until it was finally decided to standardize on a cathode of 6mm diameter and 30mm length, and an anode of 0·75mm diameter. Evacuation and gas filling were carried out through a small diameter glass tube

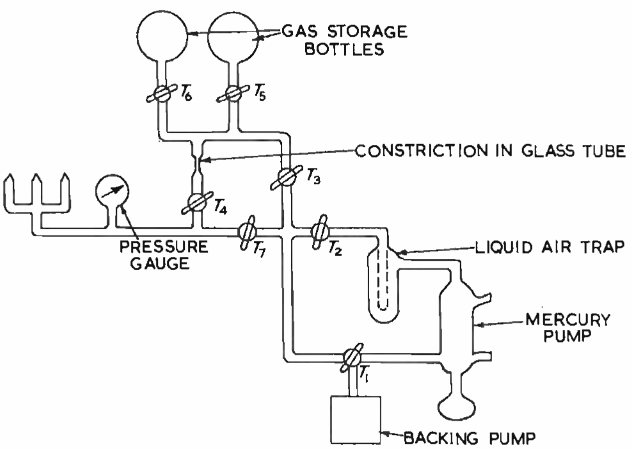


Fig. 5. Exhaust and filling system for experimental tubes

sealed to the end of the bulb. When the exhaust and filling operation was complete the tube was sealed off as shown.

The experimental tubes were processed to a schedule which consisted of baking at 360°C for 15 minutes while the tube was being pumped at a pressure of less than 10^{-5}mm of mercury.

At the end of the bake, the tubes were allowed to cool and the cathodes were outgassed by eddy-current heating until a temperature of 700-800°C was reached. Gas filling took place after the tubes had cooled down to room temperature, and the performance as stabilizers was investigated while they were still on the filling system; after this they were sealed off for further tests.

The investigation of the behaviour of many gases and gas mixtures necessitated building a special pumping and filling apparatus; Fig. 5 shows this diagrammatically. When gas mixtures were prepared on the pump, the volume between T_4, T_5 and T_6 was evacuated via T_3 to eliminate the possibility of diffusion of the first gas into the storage bulb of the second gas. In order to let in small amounts of gas, a small bore constriction was included in the filling line between the storage bulbs and the manifold. By this means it was possible to increase the pressure very slowly.

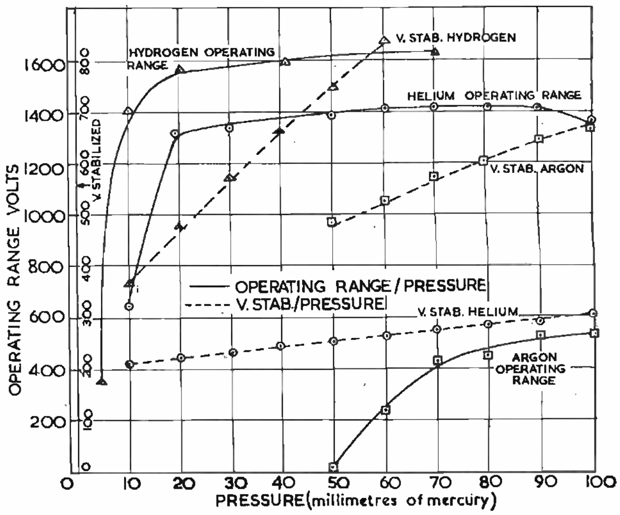


Fig. 6. V_s and operating range versus pressure

Tube Characteristics—Experimental Results

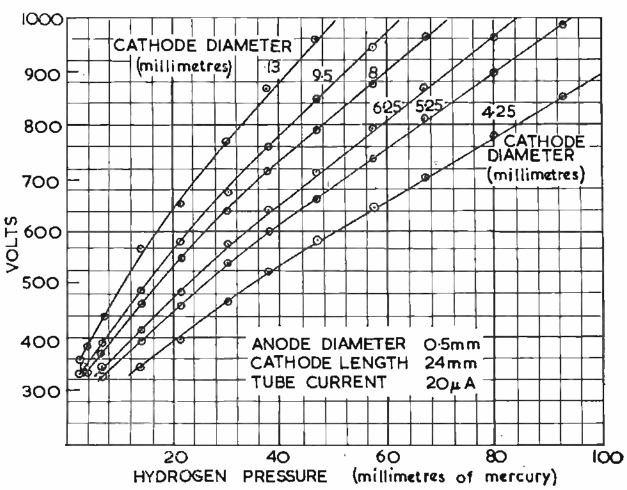
The corona discharge tube characteristics to be investigated are, the stabilizing voltage V_s, the incremental or A.C. resistance R_c, and corona range or the range of current over which the regulating action is satisfactory.

"Operating range" for the purpose of the investigations recorded in Fig. 6, is defined as the change of input voltage necessary to increase the tube current from I_{min} to 100μA at V_s. Throughout the experiments related to Fig. 6, the value of R_s was 20MΩ, and that of R_1 was 10MΩ. The top limit of 100μA was chosen because small current consumption was one of the requirements stated at the commencement of this work. Later work has shown that tube currents of several hundred microamperes may be passed before I_{max} is reached. In some gases it has been found that I_{max} is set by the onset of the glow discharge, but with hydrogen it is the commencement of oscillations which is the determining factor. When the tube current is reduced, it is found that there is a limit, viz., I_{min} set either by a type of oscillation, or by the sudden cessation of the discharge.

It is reasonable therefore, to state the useful range of a given tube by quoting I_{max} and I_{min}; it will also be necessary to state maximum and minimum safe operational currents to be observed by users of these tubes.

Fig. 6, which is a plot of V_s and operating range

Fig. 7. V_s versus pressure with various cathode diameters



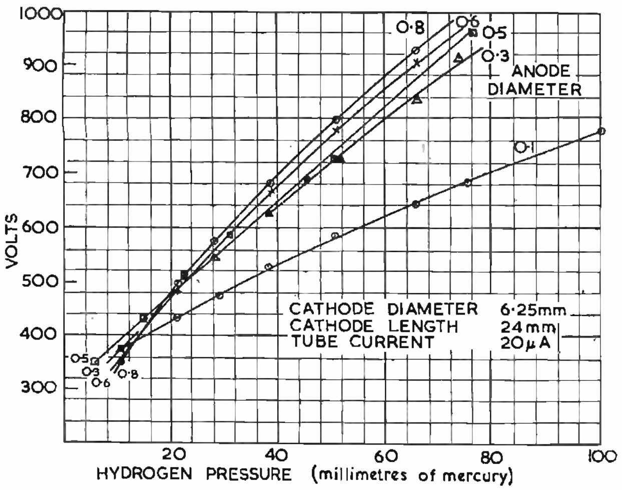


Fig. 8. V_s versus pressure with various anode diameters

against filling pressure, shows the differences which can arise from the choice of the filling gas. Fig. 7 gives the results obtained for V_s when the anode diameter, cathode length, and tube current are maintained constant, and cathode diameter and gas pressure are varied.

Fig. 8 is a similar plot for fixed cathode diameter, cathode length, and tube current, while anode diameter and gas pressure are varied. The general (and not unexpected) conclusion from these results is that V_s increases with gas pressure, cathode diameter, and anode diameter.

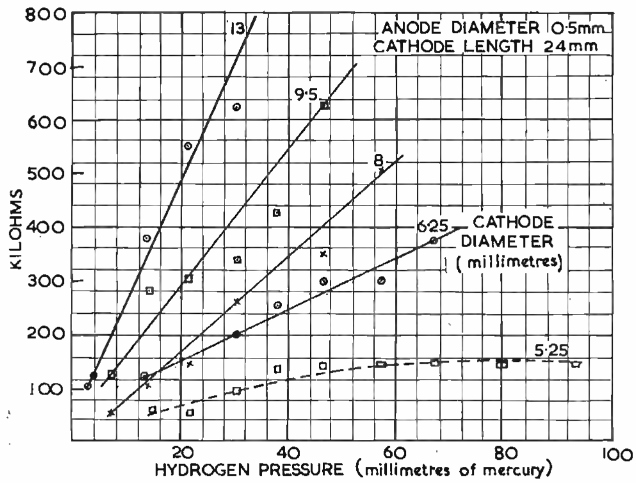
Figs. 9 and 10 show the general dependence of R_c on electrode geometry and gas pressure. It will be seen that R_c increases with gas pressure and cathode diameter, but that it decreases as the anode diameter increases.

The effect of asymmetry of the cylindrical electrode structure has also been investigated, and it has been found to have relatively little effect on V_s, but a very marked effect in lowering I_{max}. This is illustrated in Figs. 11(a) and (b).

Life Tests

The life of a tube in operational hours, and the shelf life, are of paramount importance to both users and manufacturers, so tests were carried out from the earliest experimental stages to investigate these two qualities of the corona discharge tube. In one set of tests four tubes from a batch were put on shelf test and four others on

Fig. 9. R_c versus pressure with various cathode diameters



continuous operation life test. Table 1 shows the results of the shelf test over a period of nearly three months; these can be considered satisfactory.

TABLE 1. Shelf Life Test Results

TUBE NUMBER	V_s (30-10-50)	V_s (23-1-51)
4	395	400
7	403	400
8	399	395
10	395	395

The results on continuous life test, however, showed quite clearly that the gas filling and processing of these tubes

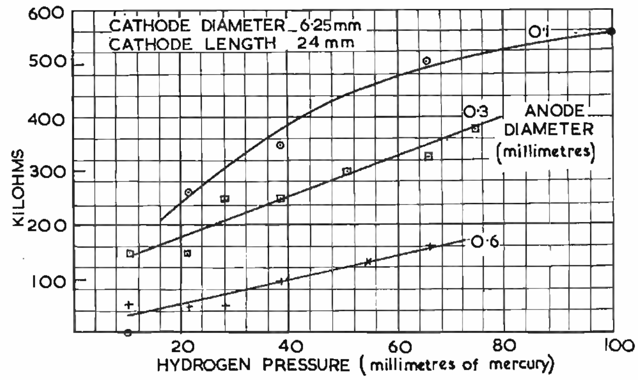


Fig. 10. R_c versus pressure with various anode diameters

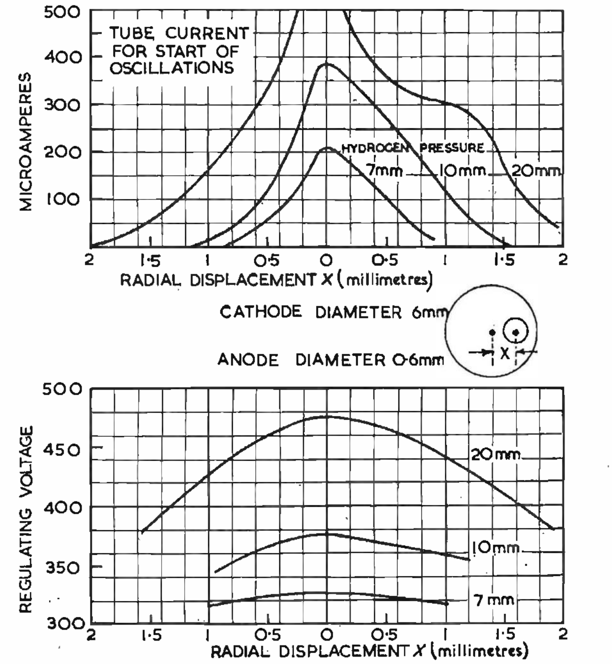


Fig. 11. Effect of radial displacement of the anode within the cathode. (a) on I_{max} (b) on V_s

was not satisfactory. There was a large drop in the value of V_s over the first 300 hours. Table 2 gives these results

TABLE 2. Early Life Test Results (showing partial recovery)

TUBE NUMBER	V_s AT START OF LIFE TEST	V_s AT END OF 300 HOURS' LIFE TEST	V_s AFTER 11 WEEKS' REST
1	412	272	390
3	402	235	380
6	400	325	390
11	410	398	410

together with the value of V_s measured after the tubes had been resting for a further period of eleven weeks. It will be seen that V_s recovers partially on standing idle.

Considerable experimentation was carried out to improve the life performance of the corona discharge tube. One interesting experimental tube used a sectioned cathode[5], constructional details of which are shown in Fig. 12. The larger portion of the cathode was processed to have a clean bright finish and the smaller upper portion, a slightly oxidized surface. This combination was used because it

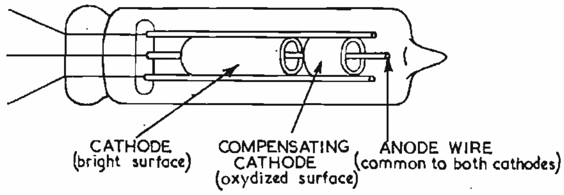


Fig. 12. Construction of sectioned cathode

had been found that an oxidized surface gave a life curve with rising V_s while that of the bright finish gave a curve falling with time. Greatly improved results were obtained with this type of tube. Improvements were steadily made to the processing and filling techniques for the single element cathode with bright finish, and Table 3 gives the values of V_s for a typical set of three tubes taken from a larger batch.

TABLE 3

HOURS OF CONTINUOUS RUNNING	TUBE NO. 2105	TUBE NO. 2128	TUBE NO. 2120
Initital	932	890	903
24	933	888	900
96	935	889	900
120	933	888	901
144	933	889	901
168	934	888	900
312	935	888	900
336	935	889	901
360	935	890	901
432	935	889	902
456	935	890	901
480	935	890	902
504	935	891	902
528	935	890	902

Other life tests have been conducted on tubes with various fillings and with various processing procedures, and from these it has been determined that:—

(a) The major change of regulating voltage during continuous operation takes place in the first 20 hours.

(b) Unsuitable exhaust and filling treatment can produce tubes with very short lives, the fault being falling V_s.

(c) It is possible to make tubes with lives which considerably exceed 1 000 hours, and this figure is now regarded as a minimum.

In consequence of (a) it was decided that all tubes should be aged for 20 hours or more as the final manufacturing process before test.

Conclusion

The work reported above gives sufficient data for the design of tubes with any regulating voltage between 400 and 1 000, operating at currents up to at least 100μA. Such tubes can be made with characteristics which are stable for considerably more than 1 000 hours.

Corona discharge tubes have already been incorporated in low power E.H.T. units for use with proportional counters (Holton and Sharpe[6]) and designs of equipment for use with Geiger counters are well advanced at A.E.R.E. Doubtless there are many other applications where the tubes described can be used with advantage.

It is known that the range of V_s can be extended to many kilovolts with appropriate increases in electrode size and gas pressure.

Acknowledgments

This work was done partly at A.E.R.E. and partly in the laboratories of N.R.D. Ltd., under a development contract from the Ministry of Supply. The writers wish to thank the Director, Atomic Energy Research Establishment, Harwell, and the directors of Nucleonic and Radiological Developments Ltd., for permission to publish this paper, and J. Sharpe of A.E.R.E. for advice freely given.

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Ultrasonics in the Foundry

The ultrasonic technique for soldering aluminium is so well known and it is being used for an increasing number of industrial processes. One particularly interesting field of application is in the foundry, where it is proving of great value for the surface treatment of faulty light-alloy castings and for the modification and repair of aluminium patterns.

The main causes for the rejection of light-alloy castings in foundries are blow-holes, dross inclusions and cracks. If these defects are severe, the faulty castings are returned to the melt. In practice, however, in spite of the care that is taken, a number of light-alloy castings are rejected on account of surface blemishes. The reclamation of such castings has for long been a pressing problem in the foundry.

In the past this problem has to some extent been overcome by filling in the surface defects with metallized glues or molten aluminium. The results, however, have never been entirely satisfactory and the repaired areas could often be detected, even after painting. With the aid of an ultrasonic soldering iron, however, surface blow-holes and cracks can now be quickly and permanently filled, and an excellent finish obtained.

The great advantage of this new soldering technique is that a strong and permanent bond is obtained between the solder and the base metal. Moreover, tin-zinc solder is used which has a texture and colour similar to that of aluminium. This means that after machining the treated areas are almost indistinguishable from the surrounding parts of the casting.

The casting is first pre-heated to the melting point of the solder used. The cavity is then filled with molten solder and the bit of the soldering iron is applied. The erosive action of the vibrating bit removes the oxide film on the sides and bottom of the hole, and rapid and effective tinning occurs. The bit is then withdrawn. If necessary further solder can be added and allowed to solidify, after which the surface can be machined to the shape of the casting.

Although the ultrasonic soldering process is quite effective for the rectification of surface defects in castings, it cannot, however, be considered suitable for jointing castings where the design is such that appreciable stresses occur across the repaired break. If, however, the part of the casting to be treated is used only for ornamentation, lap and butt joints can be used. These will withstand all normal usage.

Arrangements are being made for the Mullard Ultrasonic Soldering Equipment to be demonstrated in foundries in various parts of the country. Information regarding this, and further technical details relating to the equipment, can be obtained on request from the Equipment Division, Mullard Ltd.

Some Notes on

Ageing Processes in Instrumentation

By R. H. Mapplebeck*

ONE aspect of electronic instrumentation that is of prime importance in these days of exact requirement is the maintenance of operational accuracy and stability with time.

Performance specifications claimed for an instrument by its manufacturer are, as often as not, taken for granted by those who seldom pause to consider the close attention to detail that has made such claims possible.

In this connexion ageing plays a major part, and the object of these notes is to bring to notice some of the practical operations governing the processes that fall into this category.

General

Operational performance variation may be occasioned by changes that take place in the physical structure of the materials from which the instrument is built, and steps must therefore be taken at a suitable point during manufacture to prevent such changes occurring subsequent to calibration.

Many of these changes are due to stresses and strains set up as a result of casting, quenching, machining, cold working, welding and soldering the parts which make up the complete equipment ; others are due to variations in the characteristics of vacuum and gas-filled valves. The ageing processes employed to obviate these variations in whole or part invariably utilize some form of heat application either continuously or cyclically and may in fact be regarded as annealing processes often designed to produce a definite micro-structure or to bring about changes in structure of a sub-microscopic nature that, although not visible, are marked by changes in physical characteristics.

Magnetic Materials

Stability in delicate measuring instruments is essential, and magnetic materials are often aged by boiling in water or retaining at say, 100°C by suitable means for a pre-determined length of time dependent on the degree of final stability required.

Typical is cobalt magnet steel which is quenched at about 950°C and usually aged for five hours at 100°C. Other types of magnetic material require ageing according to the constituents of the steel. The degree of ageing is the core loss ageing coefficient expressed in watts per pound of material (the core loss being the iron losses due to hysteresis and eddy currents) and is equal to the percentage change in the standard core loss after continual heating at 100°C for 600 hours, a positive sign indicating an increase in loss.

Resistors

Owing to their high temperature coefficient, carbon resistors are not suitable where extreme accuracy and stability are required, but are often the only kind that can be employed in certain radio frequency circuits requiring non-reactive elements.

Individual opinions as to the best methods of ageing wire-wound resistors differ, but in general, baking for about four hours at 150°C is sufficient to remove the strains and stresses introduced into the wire by the act of winding whether on bobbin or former, fixed type or variable.

In cases where extreme stability is required it may be found more advantageous to apply alternate heating and cooling cycles at periodic intervals commencing at say, 150°C and reducing the temperature at the beginning of each cycle by a pre-determined amount.

A usual production routine is : (a) wind, (b) bake, (c) measure, (d) pull down turns to correct value by removing wire. It may be necessary to re-bake following soldering to tags or sub-assemblies.

Apart from such preliminary ageing, resistors that are to be adjusted during the calibration of an instrument should be further aged by running the completed instrument for several hours at normal operating voltages in case, as frequently occurs, the act of pulling down the turns and soldering has introduced errors.

Table 1 exemplifies the ageing cycles of five typical wire-wound resistors wound on ceramic bobbins with Eureka double silk covered wire, during an actual ageing production test.

TABLE 1

Change in resistance of five wirewound resistors after two 4-hour heating cycles from 150°C

RESISTOR NUMBER	INITIAL RESISTANCE (OHMS)	FIRST CYCLE (OHMS)	SECOND CYCLE (OHMS)	FINAL CHANGE PERCENTAGE
1	2649·6	2649·4	2650·0	+0·01
2	2656·2	2655·0	2655·3	−0·02
3	2656·0	2655·0	2655·1	−0·03
4	2764·3	2761·6	2762·4	−0·1
5	2569·5	2568·4	2569·0	−0·02

To ensure complete cooling to room temperature at least three hours were allowed to elapse before taking measurements after each four hour ageing cycle, and although small variations are apparent between individual resistors, probably due to variations in winding tension, a general rule would seem to be indicated that the resistance falls at first followed by a small increase.

The same rule was found to apply when other batches of resistors were aged in a similar manner, but further heat cycles produced no further useful data, only very minor changes of an erratic nature which could be dismissed as due to changes in ambient temperature and to the human element.

After ageing, it is usual to impregnate wire-wound resistors of this type with some form of insulating and moisture-resisting wax or varnish. In this connexion it is important to avoid those varnishes that may be slightly hygroscopic such as shellac which, if used on high resistance bobbins, is liable to introduce stresses into the winding with consequent production of errors due to changes in tension of the shellac covering under varying atmospheric conditions.

Capacitors

Fixed capacitors are aged in a similar manner to resistors and as far as quantity production goes, manufacturers have their own methods of handling and rapid testing. One such method is to arrange a rotatable turret into which the wire-

* *Marconi Instruments, Ltd.*

ended capacitors can be clipped, the whole then being enclosed in a compartment with controlled heating arrangements. By hand rotation of the turret each capacitor in turn may be switched into an oscillatory circuit, the frequency being monitored by a cathode-ray oscilloscope or other means. Indication is given of the end point of a heating or cooling cycle by no further change in frequency.

Precision air-spaced variable capacitors are run through ageing cycles which may consist of as many as ten cycles from cold (ambient) to 150°C at the commencement, falling to a final cycle starting at 60°C, ensuring that all nuts and bolts are tight after the fifth and tenth cycles. Another method may be to apply the following :—

1st cycle from cold (ambient) to 100°C.
2nd ,, ,, ,, ,, ,, 80°C.
3rd ,, ,, ,, ,, ,, 70°C.
4th ,, ,, ,, ,, ,, 60°C.

It may take at least one hour fully to heat the capacitor at each heating cycle and as long as two hours to cool it if cooled naturally at room temperature.

The graph, Fig. 1, illustrates the capacitance changes in pF during several ageing cycles on a good quality air-spaced variable capacitor of the type used for tuning the R.F. oscillator of a standard signal generator. It demonstrates that the bulk of the change takes place at the commencement of the heat runs so that unless extreme stability after calibration is required, a comparatively short ageing cycle is sufficient.

Valves

The necessity for ageing valves to be used in certain critical circuits, other than ageing already carried out by the manufacturers, usually only applies to mains type valves of either miniature or high slope characteristics where the electrodes lie in close proximity to the cathode, but there are exceptions, especially where gas-filled valves are concerned.

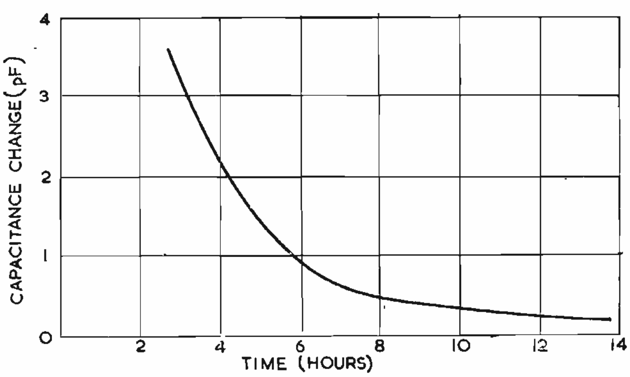
In general, increased emission takes place at microscopic high spots on the cathode, the surface at these points tending to wear down more rapidly so that after many hours normal running a reasonably uniform cathode surface obtains giving a constant emission with time.

Valve ageing processes in the instrument test room usually consist in running the valves at normal operating voltages with load values appropriate to the circuit in which they will be used, for a period of about 50 hours, though in special cases up to 200 hours may be required.

When ageing diodes it is sometimes found sufficient merely to strap the diode anode to the cathode, which simplifies ageing in the factory where large numbers of valves may require to be aged at a time on a single large board or rack fitted with the requisite valve sockets and supplied from a suitable power source.

The "splash" current curve, Fig. 2, of the ageing characteristic of a diode with time shows the need for such treatment, and although the use of an unaged diode may not adversely affect the linearity of actual measurements, it may readily cause instability of zero level with time depending upon the use to which the diode is put.

Fig. 1. Ageing characteristic of variable air-spaced capacitor with four heating and cooling cycles



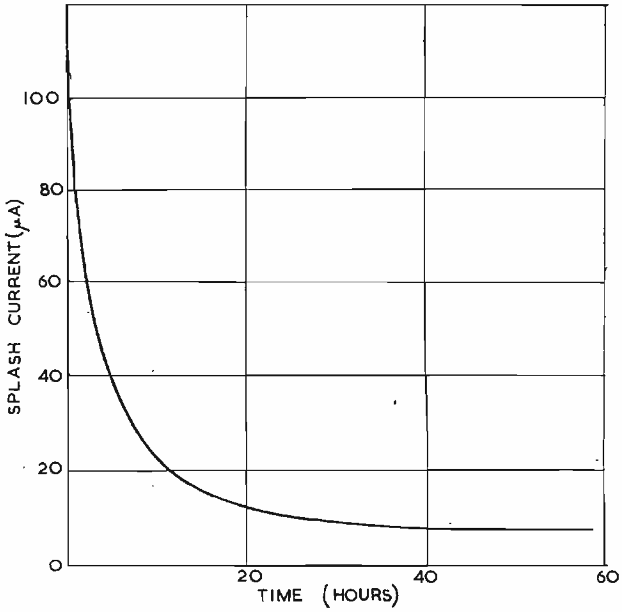


Fig. 2. Diode ageing characteristic

Complete Instruments

In spite of individual component ageing, it is frequently found essential to age the complete equipment before finally calibrating, to offset changes in impedance that may have taken place due to stresses and strains set up as a direct result of assembling and wiring. Here, it is found that high temperature baking or running at normal voltage is not the only criterion and in certain circumstances it is necessary to allow instruments to stand in store for several weeks before final calibration. The gradual ageing or relaxation of strain that then takes place is partly due to the long term effects of the small differences between night and day temperatures.

Conclusion

Although percentage change in value of an individual component parameter with ageing, may not exceed say, 0·5 per cent, yet the total lumped changes occuring with time in an instrument employing unaged components may eventually cause measurement errors after final calibration of the order of 2 per cent if the processes outlined are not carried out ; and it will be generally agreed that errors of this order can scarcely be tolerated.

Baird Special Purpose Tape Recorder

During the recent Air Exercise "Ardent" three special Tape Recorders manufactured by Baird Television were used by the Home Office. They were installed at selected Royal Observer Corps Group Headquarters in order to monitor the Home Office reporting circuits used by the Warning Officers operating in those headquarters.

When the recordings are played back the messages can be examined for inaccuracies or superfluities with a view to the introduction, where necessary, of a more streamlined procedure.

The machines record two tracks simultaneously. On one of these is recorded speech and on the other the speaking clock TIM or a spoken time reference. Voice control of the tape drive unit is incorporated to economize in tape and to ease the work of the examiners when the exercise is played back.

Distortion and Gramophone Reproduction

A Review

By M. L. Gayford, B.Sc., A.M.I.E.E., D.I.C.

IN order to achieve realism in sound reproduction it is necessary to keep distortion of the signal below certain minimum or threshold values, which represent the point at which any further improvement will not be noticeable. Distortion is defined in the most general way as any departure of the reproduced sound from the original form.

This applies to the whole reproducing chain, and distortion introduced by a given link in the chain must be either below the required threshold r must be compensated by an inverse form of distortion in another link. Generally such compensation is only possible for certain types of distortion. For example, a non-flat frequency response and certain types of phase distortion can be compensated, while non-linear amplitude distortion cannot usually be compensated. Distortion may be classified as follows:—

(1) *Frequency distortion* or non-flat frequency response.

(2) *Non-linear or amplitude distortion,* which represents a non-linear relationship between input and output power. In general, spurious harmonics and intermodulation tones are produced. It is usually measured in terms of the percentage of total harmonics produced when a single frequency is handled, though the use of intermodulation tests using two tones is increasing[1]. The relative amplitude of the two tones must be specified.

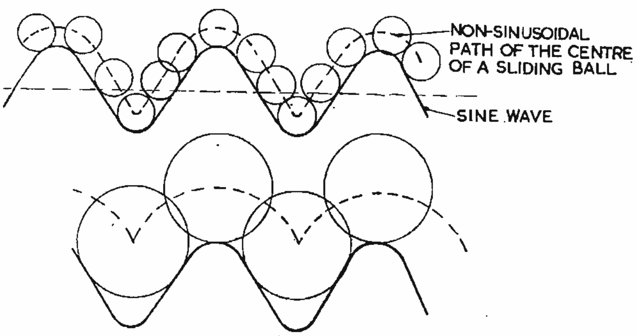


Fig. 1. The origin of geometrical tracing distortion and tracing loss for a "hill and dale" or vertical recording

(3) *Transient distortion,* which means that the actual wave shape of a transient differs at the output compared to the input. The criterion for perfection is that the frequency response of the system must be flat and that the time of propagation of all frequencies through the system must be the same. This implies that the phase-angle delay should be correctly proportional to frequency in a linear manner. There is often a tendency in electro-acoustic systems for certain frequency components of a transient to be prolonged excessively. Square wave testing and transient decay testing[2] are both used to assess transient response.

(4) *Frequency modulation or periodic variation in pitch.* Generally if the periodicity is sub-audible, "wow" is heard, while if it is in the audible range, alien tones of the F.M. sideband type are audible. This gives rise to the harshness associated with speed "flutter". These effects can arise in disk recording from causes quite independent of non-uniform rotation of the turntable[3].

(5) *Acoustic and psycho-acoustic distortion.* These forms of distortion occur through imperfections in the acoustics of studios and listening rooms, the use of mon-aural (single channel) reproducing chains, differences between the original and reproduced sound intensity and many other complicated factors. The tremendous importance of acoustic factors is now well known, but the subject is beyond the range of this discussion.

(6) *Spurious background noise* should be considered a form of distortion, but it is really a special subject and will not be dealt with in this article.

Causes of Distortion in Gramophone Pick-ups

In disk reproduction the pick up is one of the most vital links in the chain because it is subject to so many forms of distortion, most of which cannot be compensated in other parts of the chain. The following is an attempted classification.

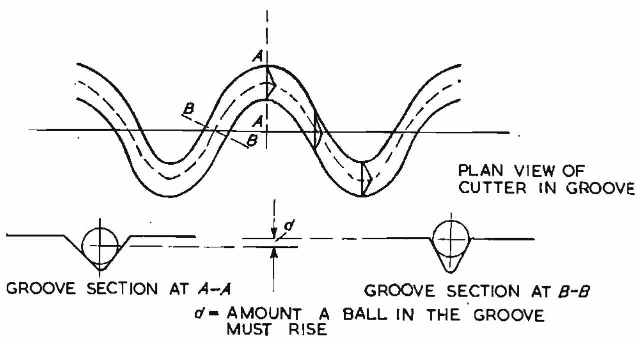


Fig. 2. "Pinch effect" due to the use of a chisel-ended cutter for lateral recording

GEOMETRICAL DISTORTION

Distortions under this heading arise from the fundamental dimensions of the groove and reproducing tip, etc., and from the geometrical relations between the various parts involved.

(a) *Tracing distortion.* This term describes a form of distortion arising from the fact that the centre of a perfect sphere sliding along a "vee" section groove with perfectly rigid walls will not trace out a sine wave when the modulation excursions of the groove are sinusoidal. This is illustrated in Fig. 1 where a circle is rolled or slid along a vertical series of sinusoidal "corrugations". It is seen that the centre of the ball does not trace a sine wave. This represents a vertical or "hill and dale" record being reproduced, and it is obvious that a stylus attached to the ball will give distorted reproduction to any transducer element it drives. Also, when the radius of the ball is larger than the radius of curvature at the bottom of the corrugation, it is seen that a "cut off" frequency is being approached and the amplitude of the output is being much reduced.

The excursions of the centre of a sphere sliding along a laterally modulated groove are more complicated because the sphere will rise and fall as well as being displaced sideways.

The angle between the two groove walls varies at different sections throughout the cycle due to the well known "pinch effect", arising from the action of a chisel-ended cutter when making the groove. (See Fig. 2). However, it is obvious that the same tendency for the centre of the sphere to follow a non-sinusoidal path will be in evidence. Actually it is discovered that, for lateral modulation, even order harmonic distortion is cancelled in a manner similar to that of push-pull valve stages. Formulæ have been derived to enable the non-linear tracing distortion to be calculated, on the assumption that the groove walls do not yield at the points of contact.

One typical formula[4] gives the third harmonic distortion for lateral recording:

$$\text{Percentage 3rd harmonic} = \frac{-0{\cdot}75\,\pi^2 R^2 f^2 u^3 / V^4}{u - 0{\cdot}25\,\pi^2 R^2 f^2 u^3 / V^4} \times 100$$

Where R = radius of stylus tip in inches

f = frequency

u = recorded velocity in inches per second peak

V = groove velocity past stylus in inches per second.

Similar formulæ[4] give the percentage intermodulation when two specified tones are played.

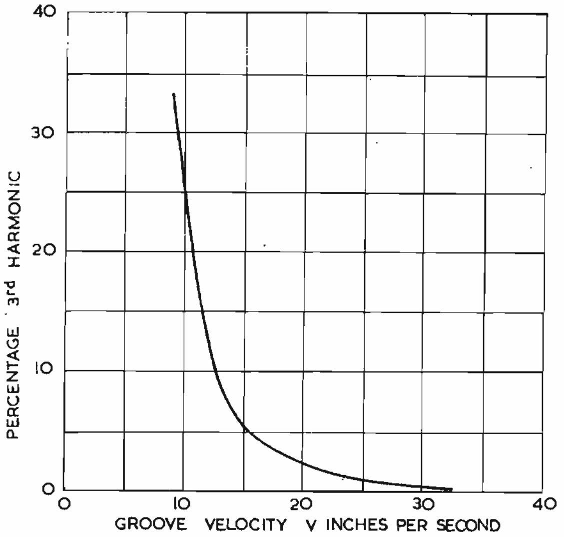


Fig. 3. Calculated tracing distortion for 4kc/s lateral recording. Stylus tip radius = 0·0023in., recorded velocity = 2in./sec peak (after Roys)

Taking 78 R.P.M. $R = 0{\cdot}003$in., $f = 3$kc/s; $u = 5$in./sec, $V = 20$in./sec.

3rd harmonic = 10 per cent approx.

Taking $R = 0{\cdot}002$in. and the other values as before:

3rd harmonic = 4 per cent approx.

This represents an extreme case which may not often occur in practice, but it shows the value of reducing the stylus tip radius as far as practicable.

It is noteworthy that if it was possible to produce the recorded groove by embossing with a spherical stylus of exactly the same radius as the reproducing stylus instead of by cutting with a chisel ended cutter, there would be no tracing distortion and no pinch effect.

Summarizing, tracing distortions can produce frequency distortion in the form of a falling top response, which can be compensated, and non-linear distortion which cannot be compensated.

In practice the effects are greatly complicated by the fact that the record material is not infinitely rigid, thus for a given material the record walls are deformed at the points of contact with a stylus of given radius to an extent depending on the mechanical impedance of the pick-up, the recorded velocity, the downward weight on the point, and the curvature of the walls. In general the curvature of one wall of a laterally modulated groove will be convex and the other will be concave and their relative deformations will be unequal. It has been claimed[5] that, for a given set of conditions, there is an optimum stylus mass which will minimize this effect and consequently give a minimum value of translation tracing loss, i.e. loss of high frequencies at the inner grooves compared to that at the outside of the disk.

Tracing distortion characteristics have the form shown in Fig. 3. It shows a sharp rise in distortion when the linear velocity of the record past the stylus falls to a certain value. This occurs when the radius of curvature of the laterial groove approaches the stylus tip radius. For a given turntable speed and stylus tip radius there is thus a limit both on the permissible signal level recorded at high frequencies and on the inner groove distance from the record centre. Good recording practice demands that one should arrange to keep below the "knee" of the tracing distortion curves at all times.

(b) *Distortion due to tracking angle errors.* With a conventional pick-up arm it is inevitable that the line along which the armature or stylus pivots will not be truly tangential to the record groove over a large part of the disk. The discrepancy at any point is called the tracking angle error. Fig. 4 shows how it can cause the pick-up to generate a distorted waveform. A formula has been developed to give

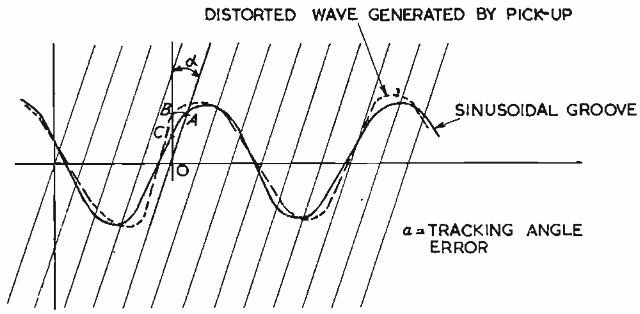


Fig. 4. Distortion produced by incorrect tracking angle. At the point "O" the stylus is moved along "OA". The output is proportional to "OB" = "OA" instead of "OC" and a distorted waveform is generated

the approximate value of second harmonic[6], assuming that the stylus system has no longitudinal compliance:

$$\text{Percentage 2nd harmonic} = \frac{\omega \,.\, A \,.\, \alpha}{W_r \,.\, R} \times 100$$

where $\omega = 2\pi \times$ frequency

A = amplitude of recording

α = tracking angle error in radians

R = radius of groove from centre spindle

W_r = rotational speed of turntable in radians per second.

For $f = 250$ cycles, $A = 0{\cdot}0017$in.

$\alpha = 5° = 5/57{\cdot}3$ Rads, $R = 2{\cdot}5$in., $W_r = 8{\cdot}16$ Rads/sec (78 R.P.M.)

2nd harmonic = 1·14 per cent

If $\alpha = 10°$, 2nd harmonic = 2·28 per cent

If $\alpha = 15°$, 2nd harmonic = 3·42 per cent.

Owing to the peculiar manner in which the distortion is produced, there is a frequency modulation effect. This has been rigorously investigated[7], and it has been shown that the second harmonic or second order, distortion greatly predominates. It is noteworthy that most pick-ups have appreciable longitudinal compliance which allows the stylus to move along the direction of the groove. This may complicate the effects considerably. However, the above simplified calculations do seem to give a fair estimate of the distortion to be expected. Design charts have been produced showing how to select the arm length, angle of offset of the head on the arm, and the amount of "over-hang", i.e. the distance the stylus will swing past the turn-table centre, so that tracking error can be reduced to a minimum[6].

(c) *Frequency modulation* of the signal or "wow" can be produced if warped or eccentric disks are used, due to the fact that the spiral track is, in effect, distorted and hence its linear speed past the stylus varies during each revolution. "Wow" can also be produced by the geometry of the pick-up head and arm in relation to the vertical pivots, because a rise or fall of the stylus point causes it to be displaced tangentially along the record groove, and hence will vary the speed of the groove relative to the stylus. The effect is minimized if the vertical points are near to the disk surface and as far as possible along the arm from the stylus point. It may become serious if one attempts to use vertically free points directly behind the pick-up head[8]. It is usually negligible for conventional pick-up designs. It has been pointed out[9] that "wow" due to the causes outlined above may easily be ±0·2 per cent and, if precautions are not taken in the recording process, may be as high as ±0·5 per cent. These amounts of "wow" may be easily audible and are outside generally accepted limits for constancy of turntable speed. The "wow" may or may not be additive to that produced by variations in turntable speed, depending on the relative phasing of the occurrences.

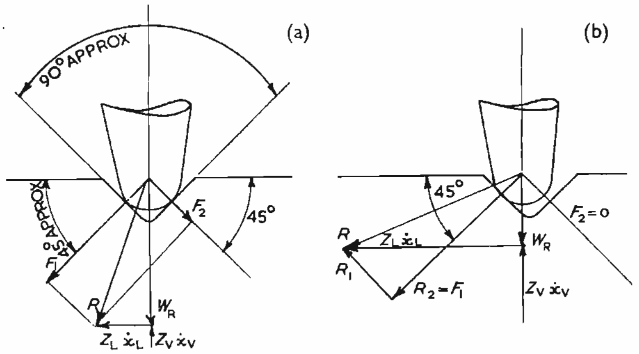


Fig. 5. Diagrams showing forces on groove walls for a lateral recording

The resultant instantaneous force on the groove is given by the vector "R." This is the resultant of the net downward force "W_R" and the force "$Z_L \dot{x}_L$" due to the lateral mechanical impedance of the pick-up. In 5(a) "R" is resolved into the forces "F_1" and "F_2" normal to the groove walls. In 5(b) "R" falls above the normal and has a component "R_1" which moves the stylus up the groove wall

Distortion Due to Erratic Following of the Groove by the Stylus*

It is necessary to distinguish this type of defect from the previous troubles described, which arise mainly from geometrical causes. Hitherto, we have assumed that the stylus maintained two-point contact with the groove walls and that its motion was entirely controlled by the lateral or vertical displacement of the groove and the geometry of the system, apart from incidental effects such as groove wall deformation. This requirement may not always be met in practice. Fig. 5(a) shows a stylus tip of the correct radius maintaining two-point contact with the groove walls. The vector diagram shows how the two resultant forces F_1 and F_2 normal to the groove walls are built up from the lateral reaction forces required to drive the stylus system, the downward weight, and the vertical reaction force generated by the lifting of the stylus due to the pinch effect. Fig. 5(b) shows how the stylus will travel up one wall of the groove when the lateral or vertical reaction forces become large enough to cause F_1 or F_2 to disappear. When this situation arises at some point during the cycle, the "following" will be erratic or discontinuous and a sharp rise in distortion will occur[1,10].

It is convenient to convert all the mechanical properties of the pick-up system to equivalent mass, stiffness and resistance at the stylus tip. The pick-up system referred to the stylus tip is inherently capable of motion in three dimensions, that is, it has a finite mechanical impedance (force/velocity) in the lateral, vertical and longitudinal directions when in the groove. Usually the designer attempts to make both the lateral and vertical mass and restoring stiffness low, while maintaining the longitudinal stiffness at as high a value as possible. The effects of longitudinal movement of the stylus tip do not appear to have been analysed, but are of considerable importance[11].

When the mechanical impedance in the three directions is measured or calculated it is found to show resonant peaks and dips at certain frequencies. Some of these resonances will affect the output, while others will not. For example, resonance between the armature mass and pivot spring lateral restoring compliance, in the absence

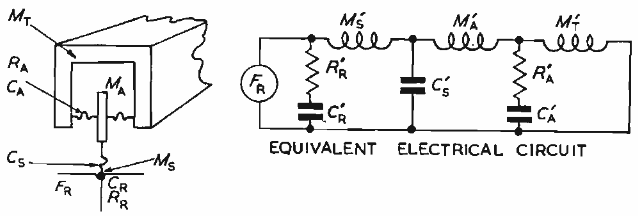


Fig. 6. Equivalent circuit of hypothetical pick-up

F_R = Driving force of groove.
C_R R_R = Mechanical compliance and resistance of record.
M_S = Mass of stylus.
C_S = Compliance between stylus and armature.
M_A = Mass of armature.
C_A R_A = Compliance and resistance of armature suspension.
M_T = Mass of pick-up head and tone arm.
The constants of the electrical circuit are the respective equivalent values referred to the stylus tip

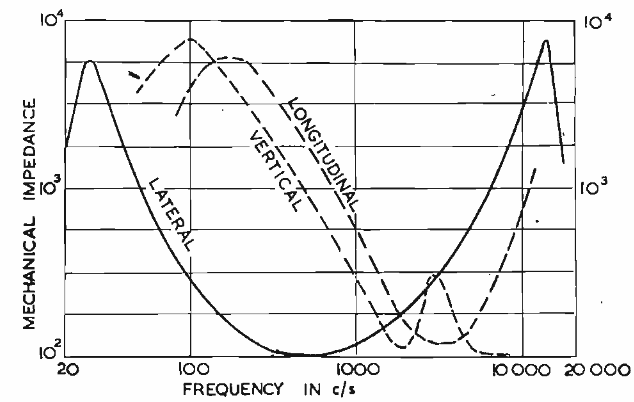


Fig. 7. Mechanical impedance characteristics of a pick-up derived from the equivalent electrical circuit

of mechanical resistance, can produce zero lateral mechanical impedance at the stylus tip at about 800c/s. The stylus will still be properly driven by the groove and the pick-up output will not be affected. However, resonance between the armature mass and the longitudinal restoring compliance of the pivot spring can cause zero longitudinal impedance at the tip in the region of 3 to 8kc/s. This may be serious, in that the stylus tip could move along the length of the groove. It is significant that an un-damped pick-up is liable to show violent distortion in this frequency region. The mechanical characteristics of a pick-up referred to the stylus tip are conveniently studied by the equivalent electrical circuit technique[12]. Here voltage corresponds to force and current to velocity, while inductance represents mass and capacitance represents compliance (the reciprocal of

* *This is often called "tracking distortion."*

stiffness). Well established theoretical methods exist for deriving such circuits[13].

Fig. 6 shows the equivalent circuit of a hypothetical pick-up. The form of the circuit may not be very different for lateral, vertical or longitudinal movements of the stylus tip, but the values of the components may be widely different in each case. Values such as the effective record wall stiffness and some of the mechanical resistances may have to be guessed at initially. The impedance/frequency characteristic of the circuits can be calculated or measured and may be as shown in Fig. 7. Horizontal and vertical reaction forces at any frequency can be estimated by multiplying the mechanical impedance by the velocity in question, and vector diagrams similar to Fig. 5 will show if the stylus can follow the groove. It is to be noted that the output of the pick-up will be given by the difference between the velocity of the armature (or moving part of the transducer element) and that of the tone arm mass. A study of these electrical circuits can lead to a much better understanding of the action of the various parts, and can help the designer considerably in proportioning the various mechanical elements of the pick-up so as to control the frequency response and groove following capabilities. A comparatively simple equivalent circuit using " lumped " constants will only represent approximately the influence of parts such as the tone arm, which may have several " internal " resonant modes in the audio frequency range[14].

There are other factors which can cause lateral and vertical forces tending to make the stylus leave the groove. Among these are " stickiness " of the tone arm pivots, " rumble " vibrations of the turntable and drive, gravitational forces due to bad levelling of the turntable, and the torque which arises from the frictional drag of the groove on the stylus and the offset angle of the head on the tone arm.

Another interesting factor is that most lateral pick-ups generate an appreciable output when the stylus performs vertical excursions, and hence the pinch effect will cause alien tones to be generated.

Transient Response

There appear to be few useful references to the transient response of pick-ups. If an accurate equivalent electrical network can be set up for a pick-up, then it can be investigated by the usual well-established electrical transient testing methods referred to earlier. An overall transient test of the system can be performed by recording and reproducing a square waveform, and it has been shown that a reasonably good square wave response can be obtained with the best modern pick-ups. It is axiomatic that a system with a response curve showing sharp resonances or high rates of frequency cut-off cannot have a good transient response[15], and thus generally a pick-up which has a wide frequency response free from resonances should have a reasonably good transient response. This pre-supposes that the conditions given in the section on correct groove following are complied with, as any instantaneous "rising" of the stylus out of proper contact with the groove will introduce transient distortion as well as non-linear distortion.

Conclusion

The task of analysing the performance of a pick-up is not easy. Simplified analyses of geometrical troubles alone show that care in design is needed to avoid quite serious amounts of distortion. Both tracing distortion and " groove following " distortion have characteristics showing a very rapid increase in distortion beyond a certain point. Some of the constructional requirements of a pick-up are mutually conflicting and problems of manufacture and physical robustness have to be considered and the final design of a high grade pick-up must therefore be a compromise between the various factors involved.

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Saturated-Diode Operation of Miniature Valves

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

Sub-miniature valves, run at reduced filament-power, may be used as saturated-diodes. The filament-power required for temperature-limited operation is only a few milliwatts and this enables the diode to be used as an amplitude-sensing device in low-power stabilizer circuits and, in place of a thermo-junction, for R.F. *measurements. The power-law relation between emission current and filament current is similar to that of diodes with pure tungsten filaments and the long-term stability is good.*

A SATURATED diode normally consists of a pure tungsten filament and a cylindrical anode. The filament is run at a temperature of 2 300°K or more and an emission of about 1mA per watt of heating power is obtained. The relationship between anode current and anode voltage is similar to that of a pentode, the anode current remaining nearly constant over a wide range of applied voltage. The anode current is, however, sensitive to changes in the filament temperature, and an increase of 1 per cent in the filament voltage will increase the anode current by 8·5 per cent (at 2 300°K). The critical dependence of diode emission-current on the filament voltage has formed the basis of a number of control and measurement circuits[1-6]. In all of these circuits the filament power required for temperature-limited operation of the diode is several watts. Campbell[7] has described a power measuring circuit known as the Diatron which uses a miniature diode running under constant temperature conditions. The

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power consumption of the diode-filament is a few milliwatts and an accuracy of power measurement of 1 per cent is claimed: unfortunately the characteristics of the diode are not given.

The resistance of a metal filament increases with temperature so that the filament itself is a non-linear element. The relation between the filament voltage V_f and filament current i_f may be expressed $V_f = K i_f^{\alpha}$, where K and α are constants. The value of K is, of course, determined by the physical dimensions of the filament, while the exponent α is about 1·6 at normal operating temperatures. Thus a 1 per cent change in filament current corresponds to a 1·6 per cent change in filament voltage. With low consumption filaments it is more convenient to measure current than voltage and for this reason the emission characteristics will be given in terms of filament current.

Directly-heated single diodes with low-consumption filaments are not generally available but there is no difficulty in using existing miniature pentodes with grid, screen and anode strapped. Temperature-limited operation is normally obtainable at about one-half of the nominal filament current which corresponds to one-sixth of the nominal filament power (see appendix). The anode characteristics

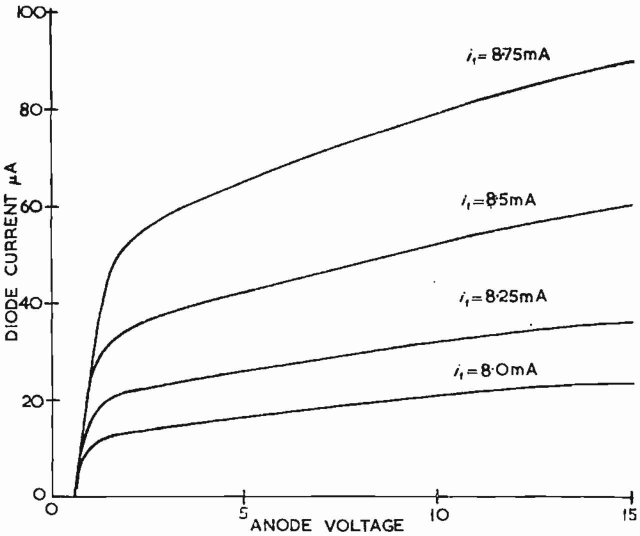


Fig. 1. DL66 anode characteristics

are not as flat as for diodes with pure tungsten filaments and for good long-term stability it is desirable to use an anode voltage of less than about 20V.

Sub-Miniature A.F. Pentode Type DL66

A typical sub-miniature pentode is the Mullard DL66. This valve has a filament rating of 1·25V at 15mA and is used as an A.F. amplifier in deaf aids. When strapped as a diode the anode characteristics are as shown in Fig. 1. If we consider a working point at an anode voltage of 5V and a filament current of 8·5mA then a change of filament current from 8·25 to 8·75mA more than doubles the emission. However, a change of anode voltage from 4 to 6V changes the emission by only 10 per cent. The relation between filament voltage and filament current is given in Fig. 2. The filament current at the chosen working point is 8·5mA and we find that the corresponding filament consumption is 4·0mW. The emission current is 40µA so the efficiency of the emitter is 10mA per watt of heating power. It has been found that if the filament current is adjusted to give an efficiency of this order of size, good stability of operation may be obtained without an inconveniently small anode current.

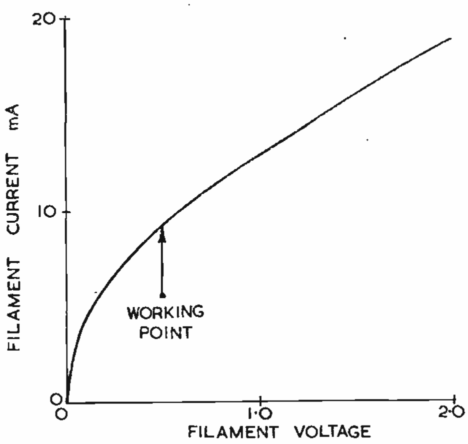


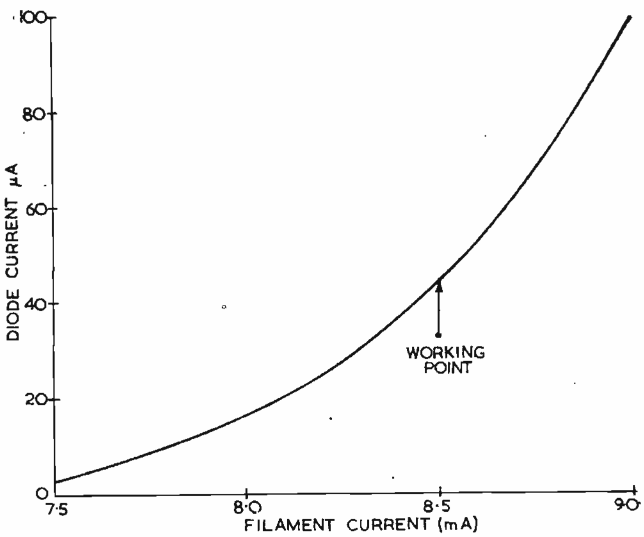
Fig. 2. DL66 filament characteristics

The relation between filament current i_f and emission current i_a at an anode voltage of 5·0V, is plotted in Fig. 3. The curve may be expressed in the form $i_a = K i_f^{\beta}$. The exponent β may be written $\delta i_a i_f / i_a \delta i_f$, i.e. the percentage change of anode current for a 1 per cent change in filament current. At the working point of i_f = 8·5mA the exponent β is 16·1.

The operating temperature of the diode filament under temperature-limited conditions is only 800-900°K, which is very much lower than the 2 300°K used in diodes with pure tungsten filaments. Due to the low working temperature the emission is affected to a small extent by ambient temperature changes. Over an ambient temperature range of 10 to 100°C the emission increases linearly with temperature at a rate corresponding to an increase in *filament* current of 0·06 per cent per °C. Ambient temperature changes in a normal room seldom exceed 5°C (9°F) which corresponds to a change of 0·3 per cent in the filament current required for a given anode current. The effect of ambient temperature changes on a diode with a pure tungsten filament is negligible[6].

When the diode is used in a control circuit, or for low frequency measurements, it is important to know the time of response of the emission current to a small change of filament current. The response time has been measured

Fig. 3. DL66 emission and filament current



with a D.C. amplifier and a direct writing recorder. At 5·0V on the anode a change of emission from 30 to 50μA is 63 per cent complete in 0·7sec and 95 per cent complete in 2·0sec. The time of response is several times as long as for available diodes with pure tungsten filaments[5,6].

The behaviour of the diode at radio frequencies was investigated by heating the filament from a wideband amplifier, see Fig. 4. The output current of the amplifier was adjusted on a thermo-junction to a constant value and the diode emission current was read on a microammeter. Over a frequency range from 10c/s to 20Mc/s the anode current was constant to within 5 per cent corresponding to a filament current constancy of $5/16{\cdot}1 = 0{\cdot}3$ per cent which is approximately the setting accuracy of the thermo-junction.

The long-term stability of the DL66 was checked by running the filament at 8·5mA from a stabilized power supply and recording the emission current. The anode potential was 5·0 volts and the high accuracy necessary in the measurement of the filament current was obtained by using a potentiometer. Over a period of 500 hours (three weeks) the change in emission corresponded to a change in filament current of approximately 1 per cent. Unfortunately emission depends to a small extent on the thermal history of the filament. The hysteresis effect is most marked if the filament current is suddenly reduced to the working value (8·5mA) after a period of running at a much higher current. Under these conditions it may be several minutes before the emission settles down to its normal value. Expressed in terms of the equivalent change in filament current the magnitude of this effect does not normally exceed 1 per cent: when

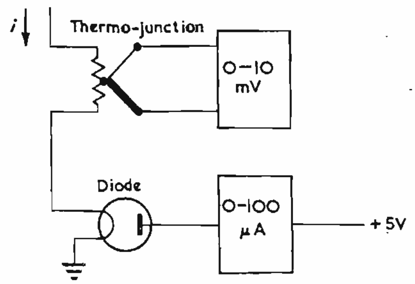


Fig. 4. Comparison of diode and thermo-junction

the diode is used as a voltage-sensing element in a degenerative stabilizer the filament temperature is substantially constant and hysteresis effects are negligible.

Miniature Pentode Type 1T4

The performance of the DL66 when used as a saturated-diode is typical of sub-miniature valves; both triodes and pentodes. For many applications an extremely low filament-consumption is not necessary and an ordinary miniature valve may be used. The 1T4 vari-mu pentode is a 1·4V miniature valve which is generally available, and it is useful to have a brief summary of its characteristics when run as a saturated-diode.

A suitable working point for saturated-diode operation of the 1T4 is at a filament current of 24mA and an anode potential of 10 volts. The emission is about 40μA and the filament consumption is 12mW, which is approximately one-sixth of the rated value of $1{\cdot}4 \times 50 = 70$mW. The power-law relating emission current and filament current has an exponent β of 14·0 at the working point. The response to a current change from 30 to 50μA is 63 per cent complete in 1·2sec and 95 per cent complete in 3·5sec. The temperature-coefficient and 500-hour stability are not much different from those obtained for the sub-miniature DL66.

It will be seen that with the exception of the filament consumption, which is 12mW instead of 4·0mW, the 1T4 has characteristics similar to the DL66.

The Application of the Saturated-Diode to R.F. Measurement

The normal method of measuring the R.M.S. value of a high frequency alternating current is to use a thermo-junction. The heater current required is usually several milliamperes and the couple itself develops an E.M.F. of a few millivolts. The voltage developed by the couple is proportional to the square of the heater current so that a change of 1 per cent in the current corresponds to a change in E.M.F. of 2 per cent. The E.M.F. is measured either on a meter or for high accuracy on a potentiometer. If a meter is to be used it is necessary that it shall be sensitive and of low resistance. For example one suitable instrument is the Cambridge Instrument Co. "Unipivot" which gives full-scale deflexion for 2·4mV and has a resistance of 10 ohms.

If a saturated diode is used in place of a thermo-junction the diode emission current is proportional to a much higher power of the filament current and a sensitive meter is not required. The DL66, diode used as shown in Fig. 4 with an anode supply of 5V, gives a change of 16 per cent in its anode current for a filament change of 1 per cent. Only a restricted range of current can be measured by a given diode so that the main application is in conjunction with an attenuator for setting the level of an R.F. signal, or as an A.C./D.C. transfer instrument. The working temperatures of the filaments of the saturated diode and the thermo-couple are not widely different so that the chances of accidental burn-out are about the same in each case.

Applications to Stabilizer Circuits

Miniature valves run as saturated-diodes can, of course, be used as amplitude-sensing elements in stabilizer circuits. A reference voltage from a neon-tube or standard cell is not required and due to the favourable relation between filament and emission current, the diode itself contributes a factor of 10 to 100 to the overall loop gain of the stabilizer. The saturated-diode is particularly useful in low voltage stabilizers running thermal devices, such as valve heaters and photometer lamps.

The design of a low voltage stabilizer using a 1T4 as a saturated-diode reference level will be described in a subsequent article.

APPENDIX

THE RELATION BETWEEN FILAMENT CURRENT AND FILAMENT POWER

The filament voltage V_f is related to the filament current i_f by the equation $V_f = Ki_f^{\alpha}$; hence, the filament power $W = V_f i_f = Ki_f^{(\alpha+1)}$. The value of α is about 1·6 so that the effect of halving the filament current is to reduce the power consumption to $0{\cdot}5^{2{\cdot}6} = 0{\cdot}165$ or approximately one-sixth of its initial value.

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The Analysis of Waves Containing Harmonics up to the Twelfth

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An article by Philip Kemp[1] dealt with the analysis up to the eleventh harmonic of waves containing odd harmonics only. The present article describes a similar method for analysing waves containing both even and odd harmonics. It was not originally intended to provide a method which would enable the twelfth harmonic to be estimated, but, as twenty-four ordinates are utilized, the magnitude of the cosine component of the twelfth harmonic can be readily obtained although the sine component cannot be found without at least one additional ordinate.

The use of as many as 24 ordinates does not arise solely out of the desire to evaluate harmonics as high as the eleventh or twelfth. By employing a larger number of ordinates than is required for the range of harmonics to be evaluated, greater accuracy can be achieved. An illustration of this is given in the above-mentioned article by Kemp. He examined the square wave utilizing his method for the analysis of odd harmonics up to the eleventh and compared the results with those obtained by an earlier method of his dealing with harmonics up to the fifth. The amount of fifth harmonic derived by these two methods was given as 21·7 per cent and 9·1 per cent respectively, while the accurate figure is 25·5 per cent. The former method gave a value of 2·2 per cent for the eleventh harmonic instead of the actual figure of 11·6 per cent. Thus, there is justification on the ground of accuracy for employing a method designed to evaluate harmonics of a higher order than those required to be estimated. Methods of the type under discussion give accurate results provided the components of the wave are limited to harmonics within the scope of the method. The procedure described herein is based on the assumption that the wave does not contain harmonics above the twelfth, but reasonable results should be obtainable, particularly with the lower harmonics, in most practical cases if the harmonics decrease rapidly with increase of frequency.

A spacing of 15° between ordinates, as used in the above-mentioned article, has been adopted as convenient, but the method described can of course be applied to other spacings by deriving suitable formulae from the basic equations in a similar manner to that employed herein.

Ordinates are drawn at 15° intervals over one cycle of the wave and the lengths of the ordinates are measured. Designating the length of the ordinate at angle $\theta°$ by $\bar{y}_\theta$ we have

$$\bar{y}_\theta = A_0 + \sum_{n=1}^{12}(A_n\sin n\theta + B_n\cos n\theta)$$

The D.C. component is first eliminated by summing algebraically the ordinates corresponding with angles from 0° to 345° and dividing the result by 24, i.e. by the number of ordinates. The D.C. component so found is then subtracted algebraically from each ordinate. Having eliminated A_0 in this way the basic equation becomes

$$y_\theta = \bar{y}_\theta - A_0 = \sum_{n=1}^{12}(A_n\sin n\theta + B_n\cos n\theta) \quad \ldots\ldots(1)$$

The process of determining the values of A_n and B_n is one of elimination. Firstly, the unknowns are divided into four groups, namely, A_n with n odd, A_n with n even, B_n with n odd and B_n with n even. Equation (1) can be modified to cover these four groups.

Replacing $\theta°$ by $(360 - \theta)°$, equation (1) becomes

$$y_{(360-\theta)} = -\sum_{n=1}^{12}(A_n\sin n\theta - B_n\cos n\theta)$$

Subtracting this from (1), we get

$$y_\theta - y_{(360-\theta)} = 2\sum_{n=1}^{12}A_n\sin n\theta \quad \ldots\ldots\ldots(2)$$

and, adding,

$$y_\theta + y_{(360-\theta)} = 2\sum_{n=1}^{12}B_n\cos n\theta \quad \ldots\ldots\ldots(3)$$

In this way we can deal with the sine and cosine components separately and each of these two equations can be modified so as to separate the odd and even harmonic components.

If $\theta°$ is replaced by $(180 - \theta)°$ equation (2) becomes

$$y_{(180-\theta)} - y_{(180+\theta)} = 2\sum_{n=1}^{12}A_n\sin(180n - n\theta) = -2\sum_{n=1}^{12}A_n(-1)^n\sin n\theta \quad \ldots\ldots(4)$$

Adding (2) and (4),

$$y_\theta + y_{(180-\theta)} - y_{(180+\theta)} - y_{(360-\theta)} = 2\sum_{n=1}^{12}A_n(1-[-1]^n)\sin n\theta = 4\sum_{n=1}^{11\,(n\text{ odd})}A_n\sin n\theta \quad \ldots\ldots(5)$$

since the expression is zero when n is even.

Subtracting (4) from (2),

$$y_\theta - y_{(180-\theta)} + y_{(180+\theta)} - y_{(360-\theta)} = 2\sum_{n=1}^{12}A_n(1+[-1]^n)\sin n\theta = 4\sum_{n=2}^{12\,(n\text{ even})}A_n\sin n\theta \quad \ldots(6)$$

By similar treatment applied to equation (3) we obtain

$$y_\theta - y_{(180-\theta)} - y_{(180+\theta)} + y_{(360-\theta)} = 4\sum_{n=1}^{11\,(n\text{ odd})}B_n\cos n\theta \quad \ldots\ldots\ldots\ldots\ldots(7)$$

and

$$y_\theta + y_{(180-\theta)} + y_{(180+\theta)} + y_{(360-\theta)} = 4\sum_{n=2}^{12\,(n\text{ even})}B_n\cos n\theta \quad \ldots\ldots\ldots\ldots\ldots(8)$$

Equations (5), (6), (7) and (8) form the bases of the evaluation of A_n and B_n, and, by substitution therein of suitable values of θ, specific expressions equating a function of a set of ordinates to a function of A_n or B_n are derived. For convenience, the former function is designated, depending on which of the four basic equations it is based, by P_m, Q_m, R_m or S_m where m is equal to θ divided by 15, i.e., by the angle expressed in degrees between consecutive main ordinates.

Five values each of P_m, Q_m, R_m and S_m can be obtained by putting $\theta°$ successively equal to 15°, 30°, 45°, 60° and 75° in the four basic equations. The sixth equation in the case of P_m, R_m and S_m is obtained by putting θ respectively equal to 90° in equation (5), to 0° in equation (7) and to 90° in equation (8)*. In deriving R_0 it must be remembered that $y_{360} = y_0$. It is from the Q_m group of relationships that the sine components of the even harmonics are derived and if the twelfth harmonic is to be evaluated at least one supplementary ordinate will be needed, because each of the main ordinates corresponds to a zero value of the sine component of the twelfth harmonic. Angles which are odd multiples of 7·5° will correspond to peak values of this component and the ordinates constructed at any of these points will lie half-way between main ordinates. The use of more than one supplementary ordinate may lessen errors and the choice of $\theta°$ equal to 67·5° for substitution in equation (6), entailing additional ordinates at 67·5°, 112·5°, 247·5° and 292·5°, provides a suitable solution.

To assist in making routine calculations with the aid of a table as discussed below, the following four functions are introduced :—

$$\begin{aligned} C_m &= y_\theta + y_{(180-\theta)} \\ D_m &= y_\theta - y_{(180-\theta)} \\ E_m &= y_{(180+\theta)} + y_{(360-\theta)} \\ F_m &= y_{(180+\theta)} - y_{(360-\theta)} \end{aligned}$$

*NOTE.—Substitution of 0° instead of 90° for $\theta°$ in equation (8) will also provide satisfactory results. Expressions for B_4, B_8 and B_{12} will be those derived herein, but B_2, B_6 and B_{10} will be expressed in terms of S_0 instead of S_6. These two sets of alternative expressions are possible owing to the fact that the algebraic sum of all main ordinates is zero, and the resulting relationship,

$$\sum_{m=0}^{6} S_m = 0,$$

enables either set of expressions to be transformed into the other.

The use of these supplementary functions is not applied to P_6, R_0 and S_6 because this would only result in unnecessary duplication of entries when employing the tabular method of calculation.

The above procedure produces the following defining expressions for the ordinate functions :—

$$\left.\begin{aligned} P_1 &= y_{15} + y_{165} - y_{195} - y_{345} = C_1 - E_1 \\ P_2 &= y_{30} + y_{150} - y_{210} - y_{330} = C_2 - E_2 \\ P_3 &= y_{45} + y_{135} - y_{225} - y_{315} = C_3 - E_3 \\ P_4 &= y_{60} + y_{120} - y_{240} - y_{300} = C_4 - E_4 \\ P_5 &= y_{75} + y_{105} - y_{255} - y_{285} = C_5 - E_5 \\ P_6 &= y_{90} - y_{270} \end{aligned}\right\} \quad \ldots\ldots(9)$$

$$\left.\begin{aligned} Q_1 &= y_{15} - y_{165} + y_{195} - y_{345} = D_1 + F_1 \\ Q_2 &= y_{30} - y_{150} + y_{210} - y_{330} = D_2 + F_2 \\ Q_3 &= y_{45} - y_{135} + y_{225} - y_{315} = D_3 + F_3 \\ Q_4 &= y_{60} - y_{120} + y_{240} - y_{300} = D_4 + F_4 \\ Q_{4\cdot5} &= y_{67\cdot5} - y_{112\cdot5} + y_{247\cdot5} - y_{292\cdot5} = D_{4\cdot5} + F_{4\cdot5} \\ Q_5 &= y_{75} - y_{105} + y_{255} - y_{285} = D_5 + F_5 \end{aligned}\right\} \quad \ldots\ldots(10)$$

$$\left.\begin{aligned} R_0 &= y_0 - y_{180} \\ R_1 &= y_{15} - y_{165} - y_{195} + y_{345} = D_1 - F_1 \\ R_2 &= y_{30} - y_{150} - y_{210} + y_{330} = D_2 - F_2 \\ R_3 &= y_{45} - y_{135} - y_{225} + y_{315} = D_3 - F_3 \\ R_4 &= y_{60} - y_{120} - y_{240} + y_{300} = D_4 - F_4 \\ R_5 &= y_{75} - y_{105} - y_{255} + y_{285} = D_5 - F_5 \end{aligned}\right\} \quad \ldots\ldots(11)$$

$$\left.\begin{aligned} S_1 &= y_{15} + y_{165} + y_{195} + y_{345} = C_1 + E_1 \\ S_2 &= y_{30} + y_{150} + y_{210} + y_{330} = C_2 + E_2 \\ S_3 &= y_{45} + y_{135} + y_{225} + y_{315} = C_3 + E_3 \\ S_4 &= y_{60} + y_{120} + y_{240} + y_{300} = C_4 + E_4 \\ S_5 &= y_{75} + y_{105} + y_{255} + y_{285} = C_5 + E_5 \\ S_6 &= y_{90} + y_{270} \end{aligned}\right\} \quad \ldots\ldots(12)$$

In deducing P_6, R_0 and S_6 by substitution in the appropriate equations, twice the value shown above is obtained, but in order to simplify the practical application of the method, both sides of the equations resulting from the substitutions are divided by 2.

Utilizing the above definitions of the ordinate functions, the general equations (5), (6), (7) and (8) provide the following four groups of specific equations :—

For derivation of A_n when n is odd,

$$\left.\begin{aligned} P_1 &= (\sqrt{6} - \sqrt{2})A_1 + 2\sqrt{2}A_3 + (\sqrt{6} + \sqrt{2})A_5 + (\sqrt{6} + \sqrt{2})A_7 + 2\sqrt{2}A_9 + (\sqrt{6} - \sqrt{2})A_{11} \\ P_2 &= 2A_1 + 4A_3 + 2A_5 - 2A_7 - 4A_9 - 2A_{11} \\ P_3 &= 2\sqrt{2}A_1 + 2\sqrt{2}A_3 - 2\sqrt{2}A_5 - 2\sqrt{2}A_7 + 2\sqrt{2}A_9 + 2\sqrt{2}A_{11} \\ P_4 &= 2\sqrt{3}A_1 - 2\sqrt{3}A_5 + 2\sqrt{3}A_7 - 2\sqrt{3}A_{11} \\ P_5 &= (\sqrt{6} + \sqrt{2})A_1 - 2\sqrt{2}A_3 + (\sqrt{6} - \sqrt{2})A_5 + (\sqrt{6} - \sqrt{2})A_7 - 2\sqrt{2}A_9 + (\sqrt{6} + \sqrt{2})A_{11} \\ P_6 &= 2A_1 - 2A_3 + 2A_5 - 2A_7 + 2A_9 - 2A_{11} \end{aligned}\right\} \quad \ldots\ldots(13)$$

For derivation of A_n when n is even,

$$\left.\begin{aligned} Q_1 &= 2A_2 + 2\sqrt{3}A_4 + 4A_6 + 2\sqrt{3}A_8 + 2A_{10} \\ Q_2 &= 2\sqrt{3}A_2 + 2\sqrt{3}A_4 - 2\sqrt{3}A_8 - 2\sqrt{3}A_{10} \\ Q_3 &= 4A_2 - 4A_6 + 4A_{10} \\ Q_4 &= 2\sqrt{3}A_2 - 2\sqrt{3}A_4 + 2\sqrt{3}A_8 - 2\sqrt{3}A_{10} \\ Q_{4\cdot5} &= 2\sqrt{2}A_2 - 4A_4 + 2\sqrt{2}A_6 - 2\sqrt{2}A_{10} + 4A_{12} \\ Q_5 &= 2A_2 - 2\sqrt{3}A_4 + 4A_6 - 2\sqrt{3}A_8 + 2A_{10} \end{aligned}\right\} \quad \ldots\ldots(14)$$

For derivation of B_n when n is odd,

$$\left.\begin{aligned} R_0 &= 2B_1 + 2B_3 + 2B_5 + 2B_7 + 2B_9 + 2B_{11} \\ R_1 &= (\sqrt{6} + \sqrt{2})B_1 + 2\sqrt{2}B_3 + (\sqrt{6} - \sqrt{2})B_5 - (\sqrt{6} - \sqrt{2})B_7 - 2\sqrt{2}B_9 - (\sqrt{6} + \sqrt{2})A_{11} \\ R_2 &= 2\sqrt{3}B_1 - 2\sqrt{3}B_5 - 2\sqrt{3}B_7 + 2\sqrt{3}B_{11} \\ R_3 &= 2\sqrt{2}B_1 - 2\sqrt{2}B_3 - 2\sqrt{2}B_5 + 2\sqrt{2}B_7 + 2\sqrt{2}B_9 - 2\sqrt{2}B_{11} \\ R_4 &= 2B_1 - 4B_3 + 2B_5 + 2B_7 - 4B_9 + 2B_{11} \\ R_5 &= (\sqrt{6} - \sqrt{2})B_1 - 2\sqrt{2}B_3 + (\sqrt{6} + \sqrt{2})B_5 - (\sqrt{6} + \sqrt{2})B_7 + 2\sqrt{2}B_9 - (\sqrt{6} - \sqrt{2})B_{11} \end{aligned}\right\} \quad \ldots\ldots(15)$$

For derivation of B_n when n is even,

$$\left.\begin{aligned} S_1 &= 2\sqrt{3}B_2 + 2B_4 - 2B_8 - 2\sqrt{3}B_{10} - 4B_{12} \\ S_2 &= 2B_2 - 2B_4 - 4B_6 - 2B_8 + 2B_{10} + 4B_{12} \\ S_3 &= -4B_4 + 4B_8 - 4B_{12} \\ S_4 &= -2B_2 - 2B_4 + 4B_6 - 2B_8 - 2B_{10} + 4B_{12} \\ S_5 &= -2\sqrt{3}B_2 + 2B_4 - 2B_8 + 2\sqrt{3}B_{10} - 4B_{12} \\ S_6 &= -2B_2 + 2B_4 - 2B_6 + 2B_8 - 2B_{10} + 2B_{12} \end{aligned}\right\} \quad \ldots\ldots(16)$$

Solving the equations in each of the four above groups results in the following values for A_n and B_n :—

$$
\begin{aligned}
24\sqrt{2}A_1 &= (\sqrt{3}-1)P_1+\sqrt{2}P_2+2P_3+\sqrt{6}P_4+(\sqrt{3}+1)P_5+2\sqrt{2}P_6\\
24\sqrt{2}B_1 &= 2\sqrt{2}R_0+(\sqrt{3}+1)R_1+\sqrt{6}R_2+2R_3+\sqrt{2}R_4+(\sqrt{3}-1)R_5\\
24A_2 &= Q_1+\sqrt{3}Q_2+2Q_3+\sqrt{3}Q_4+Q_5\\
24B_2 &= (\sqrt{3}-2)S_1-S_2-2S_3-3S_4-(\sqrt{3}+2)S_5-4S_6\\
12\sqrt{2}A_3 &= P_1+\sqrt{2}P_2+P_3-P_5-\sqrt{2}P_6\\
12\sqrt{2}B_3 &= \sqrt{2}R_0+R_1-R_3-\sqrt{2}R_4-R_5\\
8\sqrt{3}A_4 &= Q_1+Q_2-Q_4-Q_5\\
24B_4 &= -S_1-3S_2-4S_3-3S_4-S_5\\
24\sqrt{2}A_5 &= (\sqrt{3}+1)P_1+\sqrt{2}P_2-2P_3-\sqrt{6}P_4+(\sqrt{3}-1)P_5+2\sqrt{2}P_6\\
24\sqrt{2}B_5 &= 2\sqrt{2}R_0+(\sqrt{3}-1)R_1-\sqrt{6}R_2-2R_3+\sqrt{2}R_4+(\sqrt{3}+1)R_5\\
12A_6 &= Q_1-Q_3+Q_5\\
12B_6 &= -S_1-2S_2-S_3-S_5-2S_6\\
24\sqrt{2}A_7 &= (\sqrt{3}+1)P_1-\sqrt{2}P_2-2P_3+\sqrt{6}P_4+(\sqrt{3}-1)P_5-2\sqrt{2}P_6\\
24\sqrt{2}B_7 &= 2\sqrt{2}R_0-(\sqrt{3}-1)R_1-\sqrt{6}R_2+2R_3+\sqrt{2}R_4-(\sqrt{3}+1)R_5\\
8\sqrt{3}A_8 &= Q_1-Q_2+Q_4-Q_5\\
8B_8 &= -S_1-S_2-S_4-S_5\\
12\sqrt{2}A_9 &= P_1-\sqrt{2}P_2+P_3-P_5+\sqrt{2}P_6\\
12\sqrt{2}B_9 &= \sqrt{2}R_0-R_1+R_3-\sqrt{2}R_4+R_5\\
24A_{10} &= Q_1-\sqrt{3}Q_2+2Q_3-\sqrt{3}Q_4+Q_5\\
24B_{10} &= -(2+\sqrt{3})S_1-S_2-2S_3-3S_4-(2-\sqrt{3})S_5-4S_6\\
24\sqrt{2}A_{11} &= (\sqrt{3}-1)P_1-\sqrt{2}P_2+2P_3-\sqrt{6}P_4+(\sqrt{3}+1)P_5-2\sqrt{2}P_6\\
24\sqrt{2}B_{11} &= 2\sqrt{2}R_0-(\sqrt{3}+1)R_1+\sqrt{6}R_2-2R_3+\sqrt{2}R_4-(\sqrt{3}-1)R_5\\
24A_{12} &= (\sqrt{3}-\sqrt{2})Q_1-(\sqrt{6}-\sqrt{3})Q_2+\sqrt{2}Q_3-(\sqrt{6}+\sqrt{3})Q_4+6Q_{4\cdot5}-(\sqrt{3}+\sqrt{2})Q_5\\
12B_{12} &= -S_1-S_3-S_5
\end{aligned}
$$

The above expressions are in terms of P_m, Q_m, R_m and S_m as defined by equations (9), (10), (11) and (12) and substitution can be carried out in order to obtain equations for A_n and B_n directly in terms of the individual ordinates, but the use of the ordinate functions appears to be a practical advantage.

An important feature of Kemp's method is the schedule which he devised for use in the analysis of actual cases, and Table 1 herein is arranged to fulfil the same purpose when evaluating P_m, Q_m, R_m and S_m, spaces being provided for filling in the figures. Kemp suggested that a template could be constructed by pasting the schedule on a card and cutting away the portions of the card in the regions occupied by blank spaces thus enabling the figures to be written on paper placed below the template. This idea can be applied to Table 1 and also to Tables 2, 3, 4 and 5 which give details respectively for the calculation of A_n with n odd, A_n with n even, of B_n with n odd and B_n with n even. These tables are similar in form to the schedules given in Kemp's paper, except that functions P_m, Q_m, R_m and S_m are used in place of separate ordinates and also, in order to avoid unnecessary repetition of multiplication or division by the same number, values of A_n and B_n times a common multiple are first found, the actual values of A_n and B_n being derived after summation. A further minor difference is in retaining the square root symbol, except in the case of multipliers containing addition or subtraction signs. For calculation by slide rule, multiplication, by, say, $2\sqrt{2}$ is at least as simple as multiplying by 2·828. This, however, is a matter of personal preference.

It may appear to be unnecessary to mention that the magnitude of the n^{th} harmonic is given by $\sqrt{(A_n^2 + B_n^2)}$ and the phase-angle by $\tan^{-1}(B_n/A_n)$ but the following diagram is a useful reminder of the conditions governing the quadrant into which the phase-angle falls :—

A_n : −ve B_n : +ve	A_n : +ve B_n : +ve
A_n : −ve B_n : −ve	A_n : +ve B_n : −ve

Kemp's analysis dealt with a special case of the general problem considered here, and it is of interest to derive this special case from the equations developed herein. When odd harmonics only are present, Q_m and S_m must be zero. Thus, equations (6) and (8) give

$$y_\theta - y_{(180-\theta)} + y_{(180+\theta)} - y_{(360-\theta)} = 0$$
$$y_\theta + y_{(180-\theta)} + y_{(180+\theta)} + y_{(360-\theta)} = 0$$

whence

$$y_\theta = -y_{(180+\theta)}$$

and $y_{(180-\theta)} = -y_{(360-\theta)}$

As a result, for m successively equal to 1, 2, 3, 4 and 5, and θ equal to $15m$,

$$E_m = y_{(180+\theta)} + y_{(360-\theta)} = -y_\theta - y_{(180-\theta)} = -C_m$$
$$F_m = y_{(180+\theta)} - y_{(360-\theta)} = -y_\theta + y_{(180-\theta)} = -D_m$$

Thus, from equations (9) and (11)

$$
\begin{aligned}
P_m &= 2y_\theta + 2y_{(180-\theta)} = 2\,C_m \ (m \text{ from 1 to 5})\\
P_6 &= 2y_{90}\\
R_0 &= 2y_0\\
R_m &= 2y_\theta - 2y_{(180-\theta)} = 2R_m \ (m \text{ from 1 to 5})
\end{aligned}
$$

If these values are inserted in the equations derived in the present article for the amplitudes of the odd harmonic components, the solutions obtained by Kemp will result.

In using Table 1 it must be remembered that the length of the ordinates to be entered must have been adjusted for the elimination of any D.C. component, A_0. If a table is to be constructed for this operation, it is suggested that four columns be employed, as follows :—

1st Column. —Containing the angles at which the ordinates are constructed.

2nd Column. —For inserting positive values of measured ordinate lengths.

3rd Column. —For inserting negative values of measured ordinate lengths.

4th Column. —For inserting "adjusted" values of ordinate lengths ($y = \overline{y} - A_0$).

This arrangement enables the positive and negative measured values to be separated for summation. Ordinate lengths at 67·5°, 112·5°, 247·5° and 292·5°, not being required in the derivation of A_0, are preferably entered at the top of the columns and separated from the 24 main ordinate lengths which have to be totalled.

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TABLE 1

Derivation of P_m, Q_m, R_n and S_m

y_{15}		y_{30}		y_{45}		y_{60}		y_{75}		y_0		$y_{67\cdot5}$	
y_{165}		y_{150}		y_{135}		y_{120}		y_{105}		y_{90}		$y_{112\cdot5}$	
y_{195}		y_{210}		y_{225}		y_{240}		y_{255}		y_{180}		$y_{247\cdot5}$	
y_{345}		y_{330}		y_{315}		y_{300}		y_{285}		y_{270}		$y_{292\cdot5}$	
$C_1 = y_{15} + y_{165}$		$C_2 = y_{30} + y_{150}$		$C_3 = y_{45} + y_{135}$		$C_4 = y_{60} + y_{120}$		$C_5 = y_{75} + y_{105}$		—	—	—	—
$D_1 = y_{15} - y_{165}$		$D_2 = y_{30} - y_{150}$		$D_3 = y_{45} - y_{135}$		$D_4 = y_{60} - y_{120}$		$D_5 = y_{75} - y_{105}$		—	—	$D_{4\cdot5} = y_{67\cdot5} - y_{112\cdot5}$	
$E_1 = y_{195} + y_{345}$		$E_2 = y_{210} + y_{330}$		$E_3 = y_{225} + y_{315}$		$E_4 = y_{240} + y_{300}$		$E_5 = y_{255} + y_{285}$		—	—	—	—
$F_1 = y_{195} - y_{345}$		$F_2 = y_{210} - y_{330}$		$F_3 = y_{225} - y_{315}$		$F_4 = y_{240} - y_{300}$		$F_5 = y_{255} - y_{285}$		—	—	$F_{4\cdot5} = y_{247\cdot5} - y_{292\cdot5}$	
$P_1 = C_1 - E_1$		$P_2 = C_2 - E_2$		$P_3 = C_3 - E_3$		$P_4 = C_4 - E_4$		$P_5 = C_5 - E_5$		$P_6 = y_{90} - y_{270}$		—	—
$Q_1 = D_1 + F_1$		$Q_2 = D_2 + F_2$		$Q_3 = D_3 + F_3$		$Q_4 = D_4 + F_4$		$Q_5 = D_5 + F_5$		—	—	$Q_{4\cdot5} = D_{4\cdot5} + F_{4\cdot5}$	
$R_1 = D_1 - F_1$		$R_2 = D_2 - F_2$		$R_3 = D_3 - F_3$		$R_4 = D_4 - F_4$		$R_5 = D_5 - F_5$		$R_0 = y_0 - y_{180}$		—	—
$S_1 = C_1 + E_1$		$S_2 = C_2 + E_2$		$S_3 = C_3 + E_3$		$S_4 = C_4 + E_4$		$S_5 = C_5 + E_5$		$S_6 = y_{90} + y_{270}$		—	—

TABLE 2

Derivation of A_n when n is Odd

P_m	$24A_1$		$12\sqrt{2}A_3$		$24A_5$		$24A_7$		$12\sqrt{2}A_9$		$24A_{11}$	
	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT
$P_1 =$	0·5177		1		1·932		1·932		1		0·5177	
$P_2 =$	1		$\sqrt{2}$		1		-1		$-\sqrt{2}$		-1	
$P_3 =$	$\sqrt{2}$		1		$-\sqrt{2}$		$-\sqrt{2}$		1		$\sqrt{2}$	
$P_4 =$	$\sqrt{3}$		0	0	$-\sqrt{3}$		$\sqrt{3}$		0	0	$-\sqrt{3}$	
$P_5 =$	1·932		-1		0·5177		0·5177		-1		1·932	
$P_6 =$	2		$-\sqrt{2}$		2		-2		$\sqrt{2}$		-2	
	$24A_1 =$		$12\sqrt{2}A_3 =$		$24A_5 =$		$24A_7 =$		$12\sqrt{2}A_9 =$		$24A_{11} =$	
	$A_1 =$		$A_3 =$		$A_5 =$		$A_7 =$		$A_9 =$		$A_{11} =$	

TABLE 3

Derivation of A_n when n is Even

Q_m	$24A_2$		$8\sqrt{3}A_4$		$12A_6$		$8\sqrt{3}A_8$		$24A_{10}$		$24A_{12}$	
	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT
Q_1 =	1		1		1		1		1		0·3179	
Q_2 =	$\sqrt{3}$		1		0	0	− 1		$-\sqrt{3}$		− 0·7174	
Q_3 =	2		0	0	− 1		0	0	2		$\sqrt{2}$	
Q_4 =	$\sqrt{3}$		− 1		0	0	1		$-\sqrt{3}$		− 4·182	
$Q_{4·5}$ =	0	0	0	0	0	0	0	0	0		6	
Q_5 =	1		− 1		1		− 1		1		− 3·146	
	$24A_2 =$		$8\sqrt{3}A_4 =$		$12A_6 =$		$8\sqrt{3}A_8 =$		$24A_{10} =$		$24A_{12} =$	
	$A_2 =$		$A_4 =$		$A_6 =$		$A_8 =$		$A_{10} =$		$A_{12} =$	

TABLE 4

Derivation of B_n when n is Odd

R_m	$24B_1$		$12\sqrt{2}B_3$		$24B_5$		$24B_7$		$12\sqrt{2}B_9$		$24B_{11}$	
	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT
R_0 =	2		$\sqrt{2}$		2		2		$\sqrt{2}$		2	
R_1 =	1·932		1		0·5177		− 0·5177		− 1		− 1·932	
R_2 =	$\sqrt{3}$		0	0	$-\sqrt{3}$		$-\sqrt{3}$		0	0	$\sqrt{3}$	
R_3 =	$\sqrt{2}$		− 1		$-\sqrt{2}$		$\sqrt{2}$		1		$-\sqrt{2}$	
R_4 =	1		$-\sqrt{2}$		1		1		$-\sqrt{2}$		1	
R_5 =	0·5177		− 1		1·932		− 1.932		1		− 0.5177	
	$24B_1 =$		$12\sqrt{2}B_3 =$		$24B_5 =$		$24B_7 =$		$12\sqrt{2}B_9 =$		$24B_{11} =$	
	$B_1 =$		$B_3 =$		$B_5 =$		$B_7 =$		$B_9 =$		$B_{11} =$	

TABLE 5

Derivation of B_n when n is Even

S_m	$24B_2$		$24B_4$		$12B_6$		$8B_8$		$24B_{10}$		$12B_{12}$	
	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT	MULTIPLIER	PRODUCT
$S_1 =$	− 0·2679		− 1		− 1		− 1		− 3·732		− 1	
$S_2 =$	− 1		− 3		− 2		− 1		− 1		0	0
$S_3 =$	− 2		− 4		− 1		0	0	− 2		− 1	
$S_4 =$	− 3		− 3		0	0	− 1		− 3		0	0
$S_5 =$	− 3·732		− 1		− 1		− 1		− 0·2679		− 1	
$S_6 =$	− 4		0	0	− 2		0	0	− 4		0	0
	$24B_2 =$		$24B_4 =$		$12B_6 =$		$8B_8 =$		$24B_{10} =$		$12B_{12} =$	
	$B_2 =$		$B_4 =$		$B_6 =$		$B_8 =$		$B_{10} =$		$B_{12} =$	

A Note on Electronic Analogue Integration and Differentiation

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

WHEN designing an electronic integrator recently, the author discovered a simple and useful circuit transformation which does not seem to be widely known. It enables the error of a practical integrator to be expressed in familiar terms. A similar transformation applies to electronic differentiating circuits.

If a voltage e_1 is to be integrated with respect to time, it is desired to produce a voltage e_2 such that

$$e_2 = k \int e_1 dt$$

If we now consider a sinusoidal input $e_1 = a (\cos \omega t + \delta)$

$$e_2 = ka \int \cos (\omega t + \delta)\, dt$$

$$= ka\,(1/\omega) \sin (\omega t + \delta) + A$$

where A, the constant of integration, is dependent only on initial conditions and may be neglected here. A perfect integrator therefore has an amplitude response inversely proportional to frequency and a $\pi/2$ phase lag at all frequencies, or in j operator notation

$$e_2/e_1 = k/j\omega \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Fig. 1 shows the basic electronic integrator circuit. Feed-

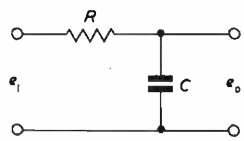


Fig. 1. Basic integrator circuit

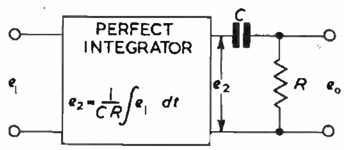


Fig. 2. Equivalent circuit

back integrators may be represented in this way if C is replaced by $C(1 + G)$ and an aperiodic amplifier of gain G is added to follow the circuit, G being the feedback gain and C the actual value of the integrating capacitor. In this circuit

$$e_0/e_1 = 1/(1 + j\omega CR)$$

Comparing this with the perfect integrator response given by Equation (1), the ratio of the actual to the theoretical output is

$$e_0/e_2 = j\omega/k\,(1 + j\omega CR)$$

Now if we put $k = 1/CR$ in this equation, it becomes the response of a *series* capacitor *shunt* resistor circuit, and we can therefore replace the circuit of Fig. 1 by the equivalent circuit shown in Fig. 2. This equivalence can also be easily proved by considering the differential equations of the two circuits. In the case of feedback integrators the response of the perfect integrator becomes $e_2 = (G/CR) \int e_1 dt$ and the capacitor value becomes $C(1+G)$.

This equivalent circuit has the advantage that it expresses the error of an electronic integrator in terms of an ordinary resistance-capacitance coupling, the properties of which are so very familiar to most electronic engineers.

In the case of a differentiating circuit, which consists basically of a series capacitor C followed by a shunt resistor R, the equivalent circuit is a perfect differentiator with a response $e_2 = CR\, de_1/dt$ followed by a series resistor R and a shunt capacitor C. If feedback is used to reduce the effective value of the resistor, the response of the differentiator becomes $e_2 = [G/(1 + G)]\, CR\, de_1/dt$, and the value of the series resistor becomes $R/(1 + G)$.

* *National Institute of Oceanography*

The Production of Fine Gauge Resistance Wires

RESISTANCE wire in a range of base metal and precious metal alloys is now available in diameters down to 0·0005in., and in certain cases smaller, with a high degree of accuracy in both diameter and resistance per unit length.

The production of such wire calls for special techniques and great experience and skill in both the wire drawing and in the preparation and maintenance of the wire drawing dies. The following is a brief description of the various processes as carried out by Messrs. Johnson Matthey and Co., Ltd.

The Drawing of Fine Wires

The raw material entering the wire shops is in the form of either extruded rod or rolled rod, which is first reduced in diameter in single die bull blocks. The material is then processed in multiple head bull blocks until it is a suitable size for passing to a multiple die wire drawing machine.

In this type of machine the wire is progressed through a series of dies of successively smaller diameter by means of multiple cone pulleys. In general, tungsten carbide dies are used for diameter reduction down to approximately 0·060in., after which diamond dies are employed. These machines operate with the dies and driving cones completely submerged in a specially prepared lubricant.

At approximately 0·008in. diameter the wire is transferred to the fine wire drawing machines in which the lubricant is restricted to the diamond dies only, the drawing cones being kept dry and in a high state of polish to ensure satisfactory operation.

The threading and setting up of a machine of this type requires great skill and experience, for wires as fine as 0·005in. diameter to be produced to close tolerances as a routine procedure.

At various stages throughout the drawing operation the wire has to be bright annealed and finally, after the completion of the drawing operation it may be supplied either hard bright, bright annealed or oxidized, according to the type of material and the customers' requirements. In general, wires are drawn on the basis of resistance per unit length and a close control is maintained on both this resistance and on the quality of the wire in terms of elongation and surface condition. For fine wires the finished product is wound on a light alloy spool designed, as an aid to the customer, to have the lowest possible inertia, the spool being packed in a strong airtight plastic container.

Die Maintenance

It can be seen that to maintain the accuracy and quality of the finished wire, it is essential that the quality and maintenance of the dies employed should be of the highest order.

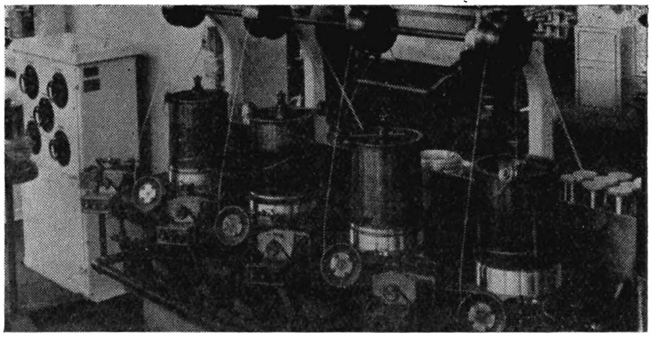
In the die maintenance shops each die, bearing a serial number, has a history sheet giving full details of its origin, size, characteristics, and of the total weight and type of wire drawn throughout its life.

The reconditioning of dies and the establishing of the correct profile of the die hole has a great bearing upon the die life and upon the quality of the finished product.

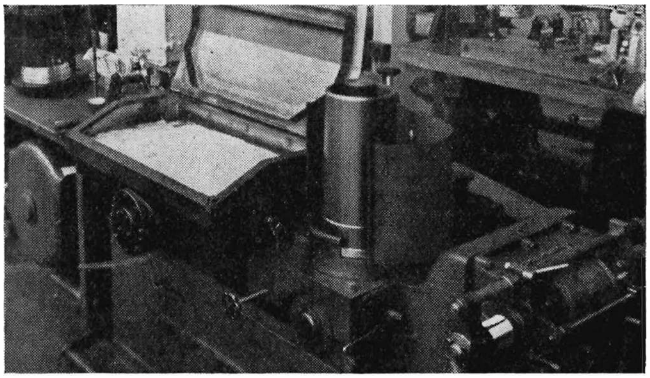
Continuous inspection of dies and of the wire drawn through these dies is essential for the consistent production of precision resistance wires.

Dies are generally re-profiled by means of vertical needle-type machines in which the die rotates and a steel needle carrying diamond powder mixed to a paste with olive oil is reciprocated in the hole. Final polishing is usually accomplished by means of wire polishing machines, in which a wire is threaded through the die, which is rotating, and reciprocates while carrying diamond paste of a suitable grade. The approach angle of the wire can be varied at will so that the various angles of the die hole can be suitably polished.

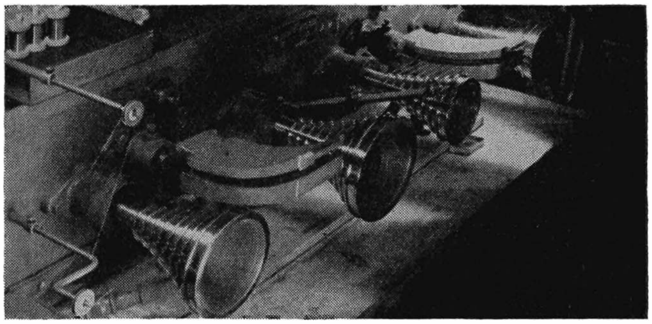
The re-profiling and polishing of a die will naturally increase the diameter and so throughout its life a die that may start with a diameter of 0·0003in. will progress step-by-step to larger sizes until finally it is no longer suitable for service.



A fine hole drawing machine on which wire is reduced to about 0·04 inch diameter.

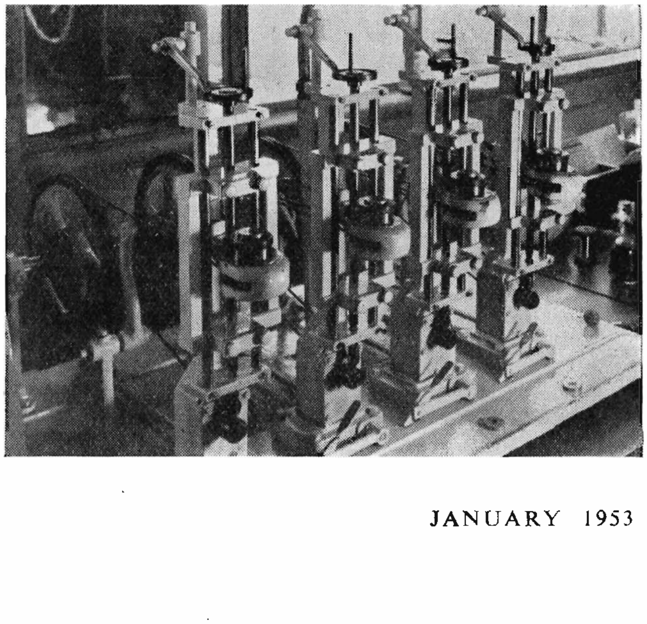


A multiple die drawing machine in which the dies are totally immersed in lubricant.



A multiple die fine wire drawing machine.

A four-position wire polishing machine used in the re-profiling of diamond dies.



LETTERS TO THE EDITOR

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

A Simple Electro-Mechanical Voltage Stabilizer.

DEAR SIR,—With reference to Mr. J. V. P. Long's article in the January, 1952, issue of ELECTRONIC ENGINEERING, I should like to point out a small modification that I used when building up an A.C. stabilizer based on his design.

Not having a D.C. split field motor I used an M-type motor normally supplied from an M-transmitter generating a step waveform approximating to an A.C. three-phase supply. The motor was supplied from an artificial three-phase supply obtained from a single-phase supply using a capacitor for the third phase.

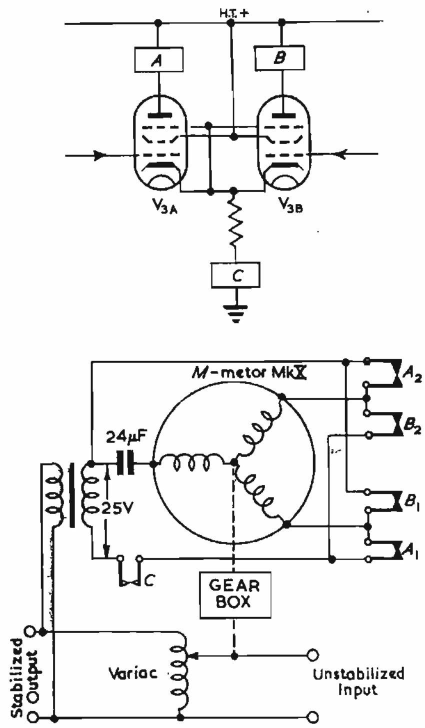


Fig. 1. Modification using M-type motor

In order to obtain forward and reverse running of the motor the connexions to any of the three motor terminals are interchanged as is normal for the reversing of a three-phase motor; this was accomplished by means of the two anode circuit relays *A* and *B* in Fig. 1. which shows the modifications to Mr. Long's circuit, the remainder being the same.

Another small point that is worth noting is that the Variac was arranged with the mains supply connected to the brush to enable the stabilizer to control even when the mains supply falls to a very low value (190 volts has been noted on occasions).

Yours faithfully,

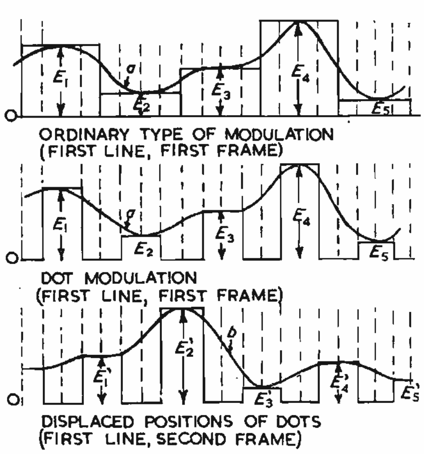
P. A. V. THOMAS, B.Sc.(Eng.),

The Royal Technical College, Glasgow.

A Compatible System of Image-Scansion

DEAR SIR,—The type of scansion described herein utilizes image-dot interlace, which provides twice as much image detail as the present day monochrome standard, without affecting the channel bandwidth. The system is based on the recognized fact that the visual response of the human eye to periodically illuminated objects is not as rapid in small areas as it is in large areas. Owing to such behaviour of the visual sense toward interrupted images, the scanned picture may be divided into a form of coarse dot structure, which may be resolved into fine detail during succeeding frame periods, by frames containing additional image dots of the same picture, interleaved in the gaps of the dots in preceding frames. In this case, each of the succeeding scanned frames will contain the same amount of visual information as it would normally contain in each frame through the present day standard mode of monochrome operation to preserve the original bandwidth restrictions. However, since each succeeding frame will contain image dots that are elementally displaced from the image dots in the preceding frame, the prolonged visual memory of the eye from frame to frame will totalize this sequence of displaced image dots, as if each frame had originally contained that amount of totalized image elements. The original continuity of picture motion will remain the same, since the frequency rate of fields and frames per second still remains the same as the present day standard. Similarly, the elementally displaced scansion will not cause any picture flicker or image twinkle, since the original position of each element, and of the frame, remains the same. In other words, as long as the position of the picture frame remains the same, the visual sense interprets the quality of the picture frame by the total amount of information it contains, and not by the elementally different positions of the image dots, and accordingly, it

Fig. 1. Mode of sampling



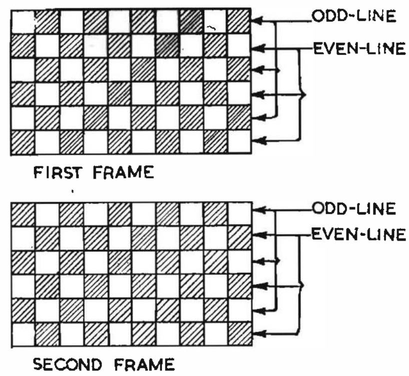


Fig. 2. Gating sequence

totalizes the image elements of succeeding frames, without awareness of any alternate illumination of the adjacent elements, even in the brightest pictures.

The mode of sampling is shown in Fig. 1. In the upper drawing, the curve *a* represents ordinary type of modulation at the transmitter, which varies in amplitude corresponding to the image elements, as shown by the square lines. In the centre drawing, the same modulation curve *a* is obtained by sampling part of the same image elements periodically, as shown by the narrow pulses. In this case, assuming that the centre drawing represents the first line of the first frame, sampling time of the image elements in the first line of the second frame is shifted, as shown in the lower drawing, so as to transmit the adjacent elements, as represented by the modulation wave *b*, and effect doubling of the image detail. Since the type of modulation is not changed from the conventional type, an ordinary type of monochrome receiver will operate without effecting any change in the reproduced picture. However, doubling of the image resolution at the receiver is accomplished by gating the beam of the image reproducing tube in synchronism with the sampling frequency at the camera tube.

Gating sequence of the beams at camera pick-up and image reproducing tube is shown in Fig. 2, the gating frequency being so adjusted that, each succeeding pattern cancels out the preceding pattern, effecting dot-less half-tone picture.

Frequency difference, or phase-drift of the gating wave at the receiving end is not critical, since the time period of each incoming signal is twice the time period of each image-illumination. Accordingly, any of the previously proposed systems of synchronization, such as used in the N.T.S.C. colour system*, may be utilized satisfactorily.

Yours faithfully.

MEGUER V. KALFAIAN,

Los Angeles, U.S.A.

* DOME, R. B., N.T.S.C. Color-TV Synchronizing Signal. *Electronics.* 25, 96. (February 1952).

ELECTRONIC EQUIPMENT

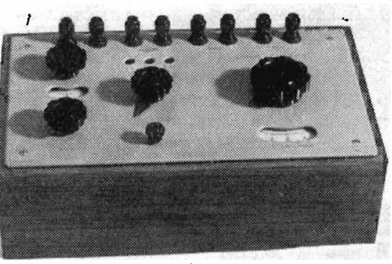
A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.

Strain Measuring Bridge Type SM3

(Illustrated below)

THE strain measuring bridge type SM3 is a general purpose bridge intended for use in the laboratory on all forms of static strain measurement with electrical resistance strain gauges of any resistance. The bridge can be used on a single gauge circuit by using the internal Apex control or it can be connected to an external Multiway Apex unit. Apex units can be supplied having up to 100 ways.

The bridge consists of a 6in. diameter slidewire, calibrated in strain, the overall range being ± 1 per cent; the slidewire is subdivided to 0·01 per cent strain. The scale has a centre zero enabling tensile strains to be read on one side and compressive strains on the other. Three range multipliers are provided, these are selected by a plug block and give × 1, × 0·3 and × 0·1. On the lowest range, the smallest division is therefore 0·001



per cent strain or 10 micro-inches per inch. A smaller dial is calibrated in gauge factor and a single Apex resistor is included for initial balancing of a single circuit. The galvanometer sensitivity control reduces the galvanometer deflexion to 1/10, 1/100 and 1/1000; the use of this control in conjunction with the non-locking galvanometer key increases the speed of operation and protects the galvanometer.

It is stated that the bridge will function correctly with resistance wire strain gauges of any make and of any resistance, the measurement being independent of gauge resistance. Optimum sensitivity is obtained with a gauge resistance in the region of 100 ohms. The bridge measures very small changes in resistance and a very high degree of stability is required on the bridge resistances to ensure that there is no drift due to the bridge during measurement. This is achieved by the design of the resistance coils and the care exercised in their construction.

The slidewire scales of the instrument are viewed through apertures in the cover and are protected by perspex cursors.

The accuracy in strain measurement is determined largely by the limits to which the gauge factor of the gauge is known. This is usually between ± 1 per cent and ± 2 per cent. The bridge itself has an accuracy within ± 1 per cent or ± ½ division, whichever is greater, except for large strains above 0·5 per cent where the error increases to ± 2 per cent. If specially required, a correction can be given for this part of the range.

The bridge can also be supplied with an alternative range of 0·5, 0·25 and and 0·1 per cent strain.

**Croydon Precision Instrument Co.,
116 Windmill Road,
Croydon, Surrey.**

Plessey E.H.T. Concentric Connectors

(Illustrated top right)

THE range of E.H.T. concentric connectors manufactured by The Plessey Company Limited, are small in size and possess high insulation properties at extremes of climatic temperature and atmospheric pressure. These connectors pass high unmatched voltages without loss of characteristic, and they are highly resistant to dimensional instability and mechanical failure.

It is claimed for the units in the range that each has adequate insulation up to 10kV for the unmatched coupling of single core concentric cables. The complete connector comprises a cable and a panel unit; the plug or socket, with its respective mouldings, can be supplied in either half of the connector according to circuit requirements.

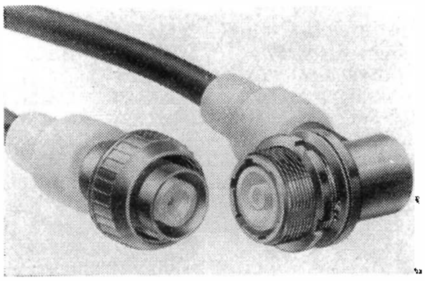
Two types are available. Of these, the demountable type is mainly for laboratory and prototype use, and where higher temperatures are encountered. The moulded type is intended for factory production, and provides greater mechanical strength. Units of both types are interchangeable with each other, and protective caps and bulkhead connectors, suitable for either, are available.

All connectors of the demountable type are externally identical, differences being confined to the outlet and split bush mouldings, gaskets and silvered contacts, to compensate for differences in cable diameter. Continuity for screening is ensured by the use of an inner and outer ferrule attached to the metal braiding of the cable and tightened into the connector by an outlet nut which also retains the mouldings. A rubber outlet sleeve is fitted over the end to effect a waterproof seal for the metal braiding.

Connector housings are of gravity die-cast aluminium with a ribbed circular coupling nut and knurled outer shell to simplify disengagement. Internal insulation is by high grade mouldings, with added insulation and pressure sealing by synthetic rubber gaskets. The internal pin and socket insert are silver-plated, and the insulating bush round each is split to facilitate soldering.

All units are fully tropicalized, and carry type approval.

The moulded version of the E.H.T. connector meets the need for components of reduced bulk and weight, with high mechanical and electrical efficiency



using Uniradio 21 and 4 cables. The aluminium housings are identical and have full mating and mounting interchangeability with the demountable version.

In these, the preformed wiring moulded *in situ* with a light shell and insulator, gives good earthing continuity between cables and longer leakage paths with reduced size and weight. Also a reduction in overall length, and the availability of right angle outlets, simplifies installation in confined spaces. Anti-vibration properties are said to be greatly improved by the positive locking of the assembly by the polythene moulding.

All units are tested to ensure full pressure sealing between face and rear, and when mated.

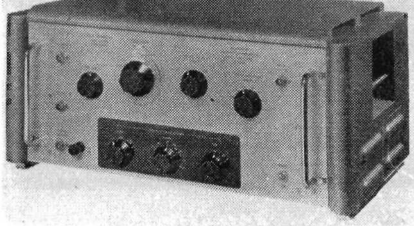
**The Plessey Co. Ltd.,
Ilford, Essex.**

Pulse Generator

(Illustrated below)

A NEW Pulse Generator, Model OPS.100, in which the main output pulse is delayable between 2 to 4 000 microseconds from the sync. output pulse has recently been produced by Solartron Laboratory Instruments, Ltd. The instrument is designed to be triggered from an external source which can be either sine waves from 50-50 000 p.p.s. or positive or negative pulses or square waves from 1-50 000 p.p.s. The main output pulse is variable in width from 1 to 100 microseconds and adjustable in amplitude on a ladder attenuator from 1 to 70 volts positive. The rise time is less than 0·1 microseconds. A sync. output of 10 volts negative is also provided.

The calibrated time delay controls are grouped on the black insulated panel and serve to provide an easy adjustment



of the position of the main pulse on the time-base trace of an oscilloscope. The delay is obtained by employing a separate variable width time delay flip-flop in the circuit, the trailing edge of its pulse being used to fire the single shot pulse generator while its leading edge is coincident in time with the sync. output. The delay circuit is free from jitter and can be used to measure response times in pulse equipment.

Solartron Laboratory Instruments Ltd.,
22 High Street,
Kingston-on-Thames, Surrey.

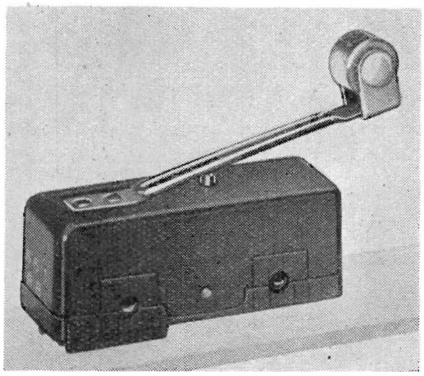
Bulgin-Acro Micro-Sensitive Switches

(Illustrated below)

NEW types in the S.500-511 group of Bulgin-Acro micro-sensitive switches can now have operating leaves fitted with end rollers. They are available in four varieties:—nickel-plated brass roller; graphite compound roller; Tufnol type roller and a stainless steel roller.

The roller facility is of advantage where the mechanism to operate the micro-switch undergoes a rotary or sliding motion with respect to the switch.

These switches have an operating life of up to a million or more operations.



with small operating forces and displacements. They have sensitive action and high current ratings. Q.M.B. contacting and quick snap-action are employed. The unit switches all have S.P.C.O. contacts to cover on-off, off-on, or change-over switching.

Bulgin micro-switches are made in this country by arrangement with the Acro Co. of U.S.A., and are in all respects interchangeable with the equivalent Acro models.

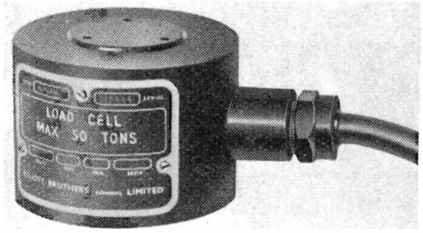
A. F. Bulgin and Co. Ltd.,
Barking, Essex.

Elliott Load Cells

(Illustrated top right)

LOAD cells for measuring forces in the range of $\frac{1}{2}$ to 200 tons have recently been produced by Elliott Bros. (London) Ltd., which convert changes in force and weight into changes in electric resistance.

The system permits the elimination of moving parts, results in a rugged installations, and enables the indication or recording of the forces to be displayed either near to the cell itself or at remote points. The cells are hermetically sealed, enabling them to be used in all atmospheric conditions.



In operation the force to be measured is caused to compress or stretch a high-tensile steel member on which current-carrying strain gauges are mounted. The gauge resistances change precisely in proportion to the applied stresses. The gauges are arranged in a bridge circuit which provides an output signal which is also strictly proportional to the applied force. This signal operates an indicating or recording instrument calibrated in terms of force, weight or percentage strain.

For temperature compensation self compensation is introduced to minimize the effects of temperature on zero reading and sensitivity. These load cells are available in the range of $\frac{1}{2}$ ton to 200 tons maximum working rating for compression or tension.

The calibration accuracy is within $\pm\frac{1}{4}$ per cent of the full range at all points from 0-100 per cent of capacity at 70° F. The recommended maximum temperature is 150° F.

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

New 16in. Cathode-Ray Tube for Television

A NEW cathode-ray tube manufactured by the General Electric Co., Ltd., has a 16in. diameter circular screen with a virtually flat face, and is aluminized.

It incorporates a triode gun. The recommended E.H.T. voltage is 12kV, the heater being rated at 6·3 volts 0·3 amperes. The tube which is designed for wide-angle scanning, has a neck diameter of 38mm, and an overall length of 460mm. A B12A duo-decal base is used, the anode connexion being made by flush side-contact.

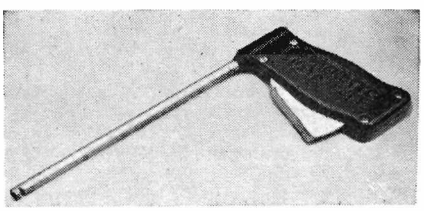
The catalogue number of this new tube is 6901A.

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

"Spearette" Trigga-snip

(Illustrated below)

THE "Spearette" trigga-snip is an instrument for cutting wires or cutting out faulty components whose positions are inaccessible to the conventional tools or the fingers.



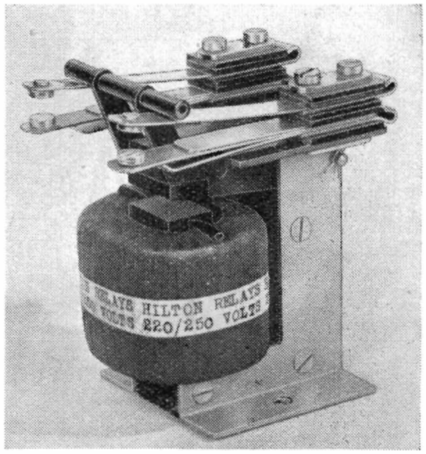
The trigga-snip can also be used for holding small components in position while they are being soldered into awkward positions, at the same time acting as a heat shunt where delicate equipment requires it. All parts of the tool are replaceable.

Spear Engineering Co. Ltd.,
Warlingham, Surrey.

The "Amp-Check"

A NEW type of circuit component named the "Amp-Check" has been designed to facilitate the measurement of electrical current by obtaining current readings directly on an ammeter without having to break the circuit to insert the meter. In addition, since there is no interruption of current flow there is also no arcing.

The component is designed for A.C. or D.C. operation. There are no power losses and no heat is generated. The "Amp-Check" is of rigid construction designed to counteract vibration and has



standard silver contacts. Provision is made for stacking a number of these devices in a circuit as required. The current carrying capacity of the component is of the order of 8-10 amperes.

Phillips and Bonson, Ltd.,
Imperial House, Dominion Street,
Moorgate, London, E.C.2.

Hilton Heavy Duty A.C. Relay

(Illustrated above)

THE Hilton type F.51 Heavy Duty A.C. Relay, available with up to fifteen pairs of 10 ampere contacts, can be supplied for use on any A.C. voltage up to 550V at normal supply frequencies.

Combinations of normally open, normally closed and change over contacts may be furnished, which will provide switching for substantial loads, and also for the informative switching required in control circuits.

The operating coils are paper interleaved and protected to withstand severe climatic conditions. The magnetic circuit is of laminated Silicon iron with accurately finished pole faces which are shaded to achieve silent 'hold-on.'

Hilton Electric Company,
67 Merridale Street,
Wolverhampton, Staffs.

BOOK REVIEWS

Vacuum Technique

By A. L. Reimann. 449 pp. Demy Octavo. Chapman & Hall Ltd., London. September 1952. Price 50s.

IN the preface of this book the claim is made by the author that he does not confine himself merely to describing vacuum equipment and techniques, but discusses at some length the underlying physical and chemical processes. Unfortunately, in the subject matter which follows, this introductory claim has been heavily biased in favour of the description of vacuum equipment. Out of 430 pages some 200 are consumed in descriptions of mechanical vacuum pumps, mercury and oil vapour pumps and vacuum gauges, most of the details of which have been well publicized in recent years.

Mr. Reimann gained much of his experience of vacuum technique during 1926-36 when he was a member of the staff of the Research Laboratories of the General Electric Company, Wembley, where he also made valuable contributions to the subjects of thermionic emission and discharge gettering. Thus it is not surprising that the most useful chapters in his book are those dealing with glass manipulation, metal to glass seals and the absorption of gases by metals and glasses. It is a pity, therefore, that the author has allowed himself to be ensnared by the apparently current theory that one cannot write a book on vacuum technique without including an all embracing description of both the historic and modern forms of vacuum apparatus. Vacuum technique has now reached an advanced stage in its development and general descriptive treaties are no longer a serious requirement. In fact one of the greatest weaknesses in the literature on vacuum technique is a shortage of works which critically review the advances made in particular fields of application.

The reviewer is not an expert on the operation of vapour stream pumps and must admit to being somewhat confused by the discussion in Chapter 5 on the age old controversy concerning the operating mechanism of this type of pump. It is stated on page 83 that the maximum streaming velocity of vapour, whether in a cylindrical or divergent nozzle, cannot exceed the speed of sound. However, the claims made by Alexander and Crawford, criticized by Reimann, of obtaining streaming velocities greater than the most probable molecular velocities would appear to be supported by recent work at the Royal Naval Scientific Laboratories. Members of the latter laboratories demonstrated at the 1950 Physical Society Exhibition supersonic flow in the vapour jet of a mercury pump excited by a high frequency discharge. Dushman also states in "Fundamental Principles of Vacuum Technique" that the vapour streaming velocity in single stage steam ejectors often has a Mach number as high as three.

The layout of the book is consistent with the publisher's high standard, but with the present high cost of technical books, it might have been wiser to have omitted those chapters already adequately covered in other publications.

L. HOLLAND.

Practical Industrial Electronics

By F. A. Arrett. 381 pp., 381 illustrations. Royal Octavo. McGraw-Hill. Price 47s.

ACCORDING to the preface to this book, the author has written it expressly for the many operating engineers and electricians, who, with little or no previous knowledge of electronic devices, are now being asked to install, operate and maintain electronic equipment. This may explain why, in places, the book reads more like an operation and maintenance instruction manual than a text book.

It is an unfortunate fact that very few authors who write on the subject of industrial electronics, manage to steer a clear course between the Scylla of too little detail about too many applications, and the Charybdis of too much detail on too few applications.

In the opinion of the reviewer the author of this book has succumbed to the second of these two perils. For example 28 pages are devoted to smoke indicators and recorders, 22 pages to combustion safeguards and 15 pages to automatic combustion control; yet high frequency heating is dealt with in only three pages of a chapter on electronic oscillators.

The use of ultrasonics for flaw detection, smoke flocculation and numerous other process applications is not mentioned at all; neither is the rôle played by electronic equipment in the measurement and recording of vibration, strain, displacement and other mechanical quantities.

Having mentioned just a few of the notable omissions from this book, it is only fair to add that the author deals very effectively with the specialized applications about which he has written.

The first seven chapters deal with the electron, electron tubes, photoelectric tubes, reactors and capacitors, electron tube rectifiers, mercury arc rectifiers and disk-type rectifiers; the treatment is clear and simple and the diagrams are particularly good.

Although the diagrams are numerous and clearly drawn, the same clarity does not extend to the section headings within the chapters; these seem to have been chosen arbitrarily and convey no real information as to the content of the section.

In his preface the author states that the book is a compilation of a number of articles which he wrote and which were published in Power between 1948 and 1951 and the book conveys this impression rather clearly; it is not as well balanced as one would wish.

Chapter 10 is entitled "One, Two and Three Stage Amplifiers" but it is disappointing because it deals only with simple resistance coupled amplifiers; in each case the output valve operates an electromagnetic relay. This is rather typical of the whole book; instead of discussing various types of amplifier such as wideband amplifiers, tuned amplifiers, negative feedback amplifiers for example, a great deal of unnecessary detail has been given on one type of amplifier. Chapter 14 dealing with smoke indicators and recorders is very comprehensive and clear and leads on fairly logically to Chapter 15 on Combustion Safeguards and Chapter 16 on Automatic Combustion Control.

Speed control of motors is covered in four chapters; Chapter 17 on Magnetic Drive Control is concerned with systems using magnetic coupling between the driving motor and the driven load, and in particular with systems employing electronic means for holding the output speed at any desired value. The next chapter is on motor and generator exciters and is followed by chapters on the speed control of D.C. motors and A.C. motors. This section of the book is presented fully and clearly and compensates in part for some of the deficiencies already mentioned. The book is essentially a specialists book and as such will have a limited appeal.

L. I. FARREN.

Materials Handling in Industry

By the British Electrical Development Association. 142 pp. Demy Octavo. September 1952. Price 8s. 6d.

THIS book is the ninth in a series on electricity and productivity dealing with specialized industrial applications of electricity. Benefits of mechanical handling, the application of mechanical handling equipment, conveyors and elevators, are among the subjects dealt with in the twelve chapters. There are over one hundred illustrations, notes and appendices.

Materials handling covers the movement of everything within factory or industrial plant and which, if reduced, immediately increases productivity. Most mechanical handling equipment is electrically operated and the use of machines to eliminate inefficient manual labour is an important part in the field of materials handling. Although there are in use today many types of mechanical handling equipment, in the majority of cases there is only one type which offers the best solution to a particular handling problem.

The chief objects of "Materials Handling in Industry" are to make easier the selection of the right device, and to show how the judicious use of electricity in this field can benefit industry.

TV Troubleshooting and Repair Guide Book. Vol. I

By Robert G. Middleton. 204 pp., 228 figs. Crown Octavo. John F. Rider Publisher Inc., New York. 1952. Price $3.90.

THIS book sets out, with the aid of numerous illustrations of waveforms and actual picture faults, to assist the service engineer in more rapid troubleshooting in television receivers. With the author's proviso in mind that "there is no substitution for study and experience" it can be regarded as a useful book, although it is, of course, only concerned with technique and standards used in the U.S.A.

The Electromagnetic Field

By Max Mason and Warren Weaver. 389 pp. Crown Octavo. Dover Publications, New York. 1952. Price (paper covers) $1.85, (cloth) $3.95.

THE reviewer's first reaction to seeing the new popular edition of this work was to place an immediate order with his bookseller, hoping that $1·85 would not be magnified too much in translation across the Atlantic. Perhaps this reaction was partly based on sentiment, for in the reviewer's college days texts on electromagnetic theory did not abound as they have done since the development of waveguides and their associated "dishes", "cheeses" and "hoghorns", so that *Mason and Weaver* stood in a class bv itself for the systematic exposition of electrical field theory. Looked at afresh, it has two slight blemishes: an unusual notation of (AB) and $[AB]$ for the scalar and vector products, respectively, of vectors A and B, and the use of Heaviside-Lorentz rationalized units. Fortunately the units are rationalized, so that the electrostatic formulæ look like the modern rationalized M.K.S. formulæ with K_0 omitted, while magnetic formulæ have μ_0 replaced by $1/c$ (c = velocity of light); and the experienced reader will have no difficulty in reconciling the formulæ as printed with the present-day M.K.S. forms, though the table for conversion of units between C.G.S. and rationalized Heaviside-Lorentz is no longer of much practical interest.

This book is not for the beginner, but its rigorous detail and refusal to gloss over philosophical difficulties should ensure it a permanent place both on the reference bookshelf and in the history of the theory of electromagnetism. It is divided into four chapters; on Coulomb's Law, The Electrostatic problem for Conductors and Dielectrics, Magnetostatics, and The Maxwell Field Equations, each of which commences with an introduction which sets out the problems to be discussed in the chapter and ends with a conclusion showing the significance of the results obtained in the chapter. As an example of thorough treatment, the chapter on Coulomb's law is divided into three parts dealing respectively with discrete charges, complexes of charge, and ponderable bodies. How many other authors examine critically the problems of progressing from the laws of point charges (to which, incidentally, electrons approximate) to phenomena which are described in terms of continuous distributions of charge? This is not an academic side-issue, for even engineers nowadays are apt to argue whether or not B and H differ by more than a numerical factor (B is of course taken as the fundamental magnetic quantity with H as a derived quantity), and one is then led to inquire whether one can talk about the field in the spaces between the molecules in a superficially continuous magnetic or dielectric medium.

With its free use of vector mathematics, *Mason and Weaver* may be "caviar to the general", but it makes a bid to be the guide, philosopher and friend of anyone seriously concerned with electromagnetism.

D. A. BELL

Teach Yourself Mechanical Draughtsmanship

By S. M. Hood. 184 pp., 203 figs. Crown Octavo. English Universities Press Ltd. 1952. Price 6s.

ANYONE with a knowledge of mechanical draughtsmanship will know that it cannot be taught in a matter of eleven easy lessons. Nevertheless it is believed that any student who is prepared, as the author of this book points out, to work hard, can teach himself draughtsmanship with its aid, and turn himself out competent to start right in as a junior. It is arranged in eleven lessons, each with exercises, giving really compact coverage of the subject.

Lesson 1 covers equipment and its use, conventional significance of different lining, lettering and dimensioning. As many drawing offices still adhere to freehand lettering exclusively, it is well to stress the importance of neat lettering in the traditional manner, but it is wondered whether the modern trend toward the use of stencils might not have been mentioned. Lesson 2 gives useful instruction in the principles of plain (the reviewer's dictionary spells this plane), geometry, as an aid to accurate drawing. Lesson 3 lucidly explains the accepted systems of projection. Lesson 4 introduces the student to isometric and oblique projections of objects of all shapes. Lesson 5 goes into details on the construction of sections through various shapes.

Although the first five lessons are liberally illustrated with figures of practical subjects, as well as simple shapes, their primary objective is to teach the principles of drawing. The remaining lessons go into real practical detail, dealing with: screw threads of all kinds; nuts, bolts, washers, screws, studs and foundation bolts; locking devices of all kinds; limits and tolerances, related to various practical applications; freehand drawing; the production of working drawings of the various kinds required throughout works production. At the end of the book are a number of useful data tables.

The author's commendable condensation of so much essential instruction and information has made possible a book at what might seem a ridiculously low price. The reviewer would like to add a word to the author's remarks about the student's preparedness to work: do not think, because the book is fairly small, that it will be assimilated too quickly; it should be thoroughly digested from cover to cover, and none of the exercises should on any account be skipped. It is all there, but the author has not unduly laboured any points.

N. H. CROWHURST.

Television Engineering

By Donald G. Fink. Second edition. 721 pp., 512 illustrations. Royal Octavo. McGraw-Hill Publishing Co. Price 72s. 6d.

ALTHOUGH published as a second edition of Principles of Television Engineering (1940) this book is virtually a new work. As pointed out by the author, all but 35 of the original 540 pages have been re-written, and only 70 out of 312 illustrations have been retained. In addition to being thoroughly revised, the new work has been expanded to include two new chapters on colour television.

To embrace the whole of modern

television engineering in a single volume is a formidable task which the author has accomplished with a substantial measure of success. Restricting attention to television broadcasting practice, it is indeed difficult to detect a single aspect of this vast subject which has been omitted.

The early chapters deal with the basic problems of image analysis and synthesis and should prove highly informative to readers possessing no previous knowledge of the subject. The salient characteristics of camera and picture tubes are described in some detail and sufficient attention has been paid to the optical aspects, both physical and physiological, to provide the reader with a useful knowledge of the entire subject. From the viewpoint of readers in this country, however, it is a pity that some of the important practical aspects are discussed with conspicuous American bias. For example, on p. 95 the flying-spot film scanner, used so successfully in this country, is dismissed in a sentence because the method is not readily applicable to the American 30 frame per sec. television standard. A further reference to the technique is made on p. 585, but the very brief description is quite inaccurate and appears to relate to the Mechau type of continuous motion projector rather than to the flying spot scanner. The statement on p. 109 to the effect that the image iconoscope is known in Great Britain as the "super-emitron" will no doubt raise a smile amongst engineers here.

A misleading statement occurs on p. 140 concerning the magnification of directly-viewed television images. The author states that a less bulky alternative to the liquid-filled plastic lens is the Fresnel lens, "a flat plastic sheet in which have been embossed a large number of circular hemicylindrical ridges." The latter arrangement does not, of course, provide image magnification, but has directional properties applicable to projection systems.

The elementary principles of electron-optics are described neatly in Chapter 4, which is concerned with scanning and synchronization, and much useful practical information is given relating to methods of beam deflexion, focusing and the generation of scanning waveforms.

The discussion on pp. 188 and 189, which concerns the effect of scanning coil resistance, is incorrect and would certainly mislead a student. Fig. 143 would apply if a zero-impedance, i.e., constant voltage scanning generator, were employed, but the use of a blocking oscillator as a sawtooth generator in Fig. 144 is a contradiction. No mention is made of the exponential distortion of the sawtooth which results from this cause when a scanning current transformer is used, as is normal practice.

In two subsequent chapters transmission and amplification of video signals are dealt with in detail and a wealth of design information is included. The emphasis throughout is on practical rather than theoretical issues and design formulae are more often stated than developed. The theoretical treatment when included is inclined to be weak and would at times better have been omitted. For example, the Fourier integral is correctly stated in Eq. (77) on p. 225, but later, on p. 242 when considering the response of an ideal filter to a rectangular pulse, the author proceeds to develop this response by integrating an incorrectly modified spectrum, without including the essential time operator. One is caused to wonder how Eq. (87) has survived proof-reading.

Considerable space has been devoted in Chapter 7 to the often-neglected aspects of carrier transmission of picture and sound signals. Important subjects such as propagation, co-channel and adjacent channel interference, aerial performance and frequency modulation have been treated in remarkable detail, bearing in mind the limited space available in a single volume.

Colour television is the subject of Chapters 8 and 9, in which colour fundamentals and colour television systems respectively are dealt with. Both are excellent and will provide the reader with comprehensive and up-to-date knowledge of the subject.

The final two chapters deal respectively with broadcasting and receiving equipment, and here the practical design of apparatus is described in detail. Quite naturally the author is concerned almost entirely with American practice, but the greater part of the information given could be applied readily to any television broadcasting standards.

An extensive bibliography is included at the end of each chapter, but it is disappointing to find that references are almost absent from the text.

In spite of the criticisms, this book will be of considerable value to the trained radio engineer who wishes to acquire up-to-date knowledge of present-day practice in television broadcasting.

G. G. GOURIET.

The Quarterly Journal of Mechanics and Applied Mathematics

Volume V, Part 3 (September 1952). 384 pp. Medium Octavo. Oxford University Press. Price 15s.

THIS issue of the Quarterly Journal contains the usual high number of interesting papers, although very mathematical in nature. One paper by Dr. D. S. Jones is unusual. Mathematicians often complain that the theoretical physicist does not trouble to prove the uniqueness of a solution of his problem, and the physicist retorts that it is obvious to him that it is unique. This paper is concerned with the diffraction of electromagnetic waves at an edge or corner, and the difficulty of imposing proper conditions there on the behaviour of the fields is such that Dr. Jones has been forced to examine what condition is sufficient to give a unique solution!

G. J. KYNCH.

Radio Research 1951

36 pp. Medium Octavo. H.M.S.O. Price 1s. 6d.

THIS is published by H.M.S.O. for D.S.I.R. and contains the report of the Radio Research Board. The report refers to the shortage of staff and suitable buildings for carrying out the growing research programme of the Radio Research Station and its branches. The Board emphasizes the importance of fundamental radio research to the defence services of the country and urges that every effort should be made to overcome these handicaps.

Most of the research work of the Radio Research Station during the year was concerned with the study of radio wave propagation over the whole frequency band, and with research into long range back-scatter from high power pulse transmitters. Research was also carried out in the directional measurement of rays reflected from the ionosphere, but research into the properties of the ionosphere at low frequencies was discontinued temporarily. The propogation of ratio waves through the troposphere, along the ground and along single wire transmission lines was also investigated.

Applied Electronics Annual, 1952

Editer by R. E. Blaise. 240 pp. Royal octavo. Bri.ish-Continental Trade Press Ltd. (London, 1952.) Price 40s.

THE chief feature of this Annual is the international directory on radio and electronic products, the five main parts covering (i) manufacturers, (ii) suppliers of component parts and materials, (iii) wholesalers, importers, agents, etc., (iv) list of trade marks and names, (v) buyers' guide. Roughly half the book is occupied with this directory. In the remainder there are chapters written in a semi-technical manner on various subjects in the field of electronics. These include "Around the Radio Markets", "V.H.F. Broadcasting and Television in West Germany", "Notes on World Television", A Description of Some B.B.C. Mobile Transmitters", etc. An article entitled "Underwater Television" comprises less than a page and is little more than an expanded title. The book lacks careful editing and co-ordinating: non-standard symbols are prominent; in one case there are four wrong versions of one symbol. The essence of such a directory is accuracy, but there are so many errors and omissions in this Annual that little confidence can be placed in it. Of the 240 pages in the book, 60 are advertising pages, so that at 40s. the book will not be universally acclaimed as good value.

E. H. W. BANNER.

The BEAMA Catalogue 1952-53

1020 pp. 2nd Edition. Iliffe & Sons, Ltd.

THE publication of this edition of the BEAMA Catalogue marks a further important stage in the British electrical industry's contribution to the nation's economy. There is a glossary in five languages which will greatly facilitate inquiries from potential overseas buyers and has been added in the light of experience gained in the world-wide distribution of the first edition of 1949-50. After the five language glossary comes the classified buyers' guide and trade directory. A full index is also included.

Altogether in this edition there are seven divisions, the illustrated descriptive pages being arranged in three main groups of products. The first is concerned primarily with requirements for a modern electricity supply system; the second with equipment used in industry, transport and communications; and the third with domestic and commercial appliances.

Notes from the Industry

Television for Siam. The English Electric Company, Ltd., and their associate company, Marconi's Wireless Telegraph Company, announce that entirely British equipment will be used by the first country in South East Asia to install television. A contract for two installations, each complete from camera to receivers, has been agreed with the Government of Thailand. The first was in operation at Chulalongkorn University, Bangkok, early in December for the opening of the Constitution Fair, and the other will be operating in the early summer.

Dr. C. F. Bareford, head of the Mullard research laboratories in Surrey, has been appointed chief superintendent of the Long Range Weapons Establishment at Salisbury and Woomera, South Australia. Mr. Beale, the Australian Minister of Supply, said that Dr. Baresford would succeed Mr. H. C. Pritchard, who is to return to the British Ministry of Supply.

The 1953 Radio Engineering Show held under the auspices of the Institute of Radio Engineers, Inc., will take place in New York from March 23rd to March 26th inclusive.

This show is considered to be one of the best of its kind in the United States and is open to manufacturers of all types of radio, communications, television and electronic control equipment. United Kingdom firms, particularly those with distribution arrangements already established in the United States, are recommended to take part. Full particulars may be obtained from the organizers, Messrs. Clapp and Polliak, 341 Madison Avenue. New York, and also from the Exhibitions and Fairs Branch of the Board of Trade, Lacon House, Theobalds Road, London, W.C.1.

New EKCO Student Apprenticeship Scheme. The management of E. K. Cole, Ltd. have announced an extension to the existing apprenticeship scheme to cover an additional grade, that of student apprentice. The object of this new scheme will be to provide a more general training than is available at present, which will equip the student apprentice for an appointment in the EKCO engineering works or office staff. These student apprenticeships will be open to present EKCO apprentices of 18 years or over with the necessary qualifications, and a limited number will be available to outside applicants.

Airmec, Ltd. telecommunication and electronic engineers have recently registered a change of name, and their official name and address is now Airmec, Ltd., High Wycombe, Buckinghamshire.

The Telegraph Construction and Mainenance Co.. Ltd., have recently opened a branch office at 43 Fountain Street, Manchester, 2, under the charge of Mr. J. Taylor.

The Research Laboratories of the General Electric Co., Ltd., of England, are proposing to set up a unit at the Long Range Weapons Establishment, Salisbury, South Australia, for trials and further development of guided weapon equipment on which they are at present working in the United Kingdom.

Pye, Ltd., of Cambridge, announce that the German authorities have decided to use British equipment in the German television service. Orders have been received for the installation of television cameras and associated equipment in Munich and Hamburg.

Arcolectric (Switches), Ltd. are now completing an extension to their factory in West Molesey. The complete factory will have a total floor space of just under 18,000 square feet and the extension will enable the company to expand output to meet the rising demand for Arcolectric switches and signal lamps.

British Electronic Products (1948), Ltd., which became one of the subsidiary companies of the Lancashire Dynamo Group in early 1950 and which has continued to expand its range of industrial electronic equipment since that date, has now changed its name to Lancashire Dynamo Electronic Products, Ltd. Manufacture and development will continue under the new title, from the same address, B.E.P. Works, Rugeley, Staffordshire.

British Insulated Callenders Cables further education scheme awards. Lt.-Gen. Sir Ronald Scobie, K.B.E., C.B., M.C., a director of the company, recently presented awards to more than 50 employee students, about one-third of whom had taken courses at the company's day continuation school which functions under the authority of the Lancashire County Council Education Committee. The remainder of the students were those who had gained successes while attending local technical colleges.

Mullard Equipment, Ltd. have recently acquired another factory at Wandsworth to cater for the increased commercial activities of the equipment division. At this new factory are housed the main assembly and production lines for all classes of equipment, as well as factory administration and service departments. Research and advanced development will continue to be done at the Mullard Company's Research Laboratories at Salfords, Surrey.

The Television Society's Annual Exhibition will be held on January 23rd and 24th at 155 Charing Cross Road, London, W.C.2, by the invitation of the Edison Swan Electric Company, Ltd. All exhibits are closely related to television engineering or production or to the production of television programmes. Tickets of admission may be obtained from members and patron members or from G. T. Clack, Lecture Secretary, 43 Mandeville House, Worsopp Drive, London, S.W.4.

The General Electric Company have recently completed shipment of specially designed H.F. and V.H.F. radio equipment for the Indonesian Police. This contract has been completed in a period of 18 months, in spite of the fact that much of the apparatus had to be designed to meet the particular requirements of the Indonesian authorities.

Marconi's Wireless Telegraph Company have received the first export order for British underwater television equipment. The order is for the supply of Marconi-Siebe Gorman equipment for dock and harbour inspection work in Jugoslavia's Adriatic ports.

Elliott Brothers (London), Ltd. have transferred their Birmingham branch office to larger and more modern premises at 181 Corporation Street, Birmingham, 4. This new branch office is now the area sales, service and instrument repair centre for the Midland counties.

Department of Mechanical Engineering, Borough Polytechnic. A course of seven lectures on the Technique of Technical Writing will be given by Mr. G. Parr, M.I.E.E., at the Borough Polytechnic, S.E.1, on Thursdays at 6.30 p.m., commencing on January 15, 1953. The fee for the course is 30s. and enrolment forms can be obtained from the Secretary, Borough Polytechnic, Borough Road, S.E.1. Mr. Parr, who is Technical Director of Chapman and Hall, Ltd., was formerly Managing Editor of ELECTRONIC ENGINEERING.

Television talks with BBC. Meetings have taken place in London recently between the BBC and representatives of Radiodiffusion et Television Francaise to discuss the possibility of relaying the coronation television programmes to France. No decision by RTF as to whether or not they will transmit BBC coronation programmes will be available until the conclusion of a series of tests which it is hoped to carry out early in the New Year.

Meetings this Month

THE BRITISH INSTITUTION OF RADIO ENGINEERS

Date: January 5. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine.
Lecture: The Modern Single-Layer Selenium Photocell.
By: G. A. Veszi, Ph.D.

Scottish Section

Date: January 8. Time: 7 p.m.
Held at: The Institute of Engineers and Shipbuilders, Glasgow.
Film Evening.

North-Eastern Section

Date: January 14. Time: 6 p.m.
Held at: The Institution of Mining and Mechanical Engineers, Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Lecture: Hearing Aids.
By: R. A. Bull, B.Sc.(Eng.).

Merseyside Section

Date: January 15. Time: 7 p.m.
Held at: The Electricity Service Centre, Whitechapel, Liverpool.
Lecture: Design and Application of Quartz Crystals.
By: R. A. Spears, A.M.Brit.I.R.E.

West Midlands Section

Date: January 27. Time: 7.15 p.m.
Held at: Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.
Lecture: The Search for Bandwidth Economy in Television.
By: D. A. Bell, M.A., B.Sc.

BRITISH KINEMATOGRAPH SOCIETY

All London meetings, unless otherwise stated, will be held at The Gaumont-British Theatre, Film House, Wardour Street, London, W.1, at 7.15 p.m.

Date: January 7.
Lecture: Films and Their Story.
By: Cecil M. Hepworth, Hon. F.B.K.S., Hon. F.R.P.S.

Date: January 14.
Lecture: Modern Tendencies in 16 mm. Projector Design.
By: C. B. Watkinson, M.B.K.S.

Date: January 21.
Programme of Films—Outstanding 16 mm. Film Productions.
Admission by ticket only, obtainable from the Secretary before January 14.

Date: January 28.
Lecture: The Use of Film in Television Production.
By: Ian Atkins.

Date: January 13. Time: 11 a.m.
Held at: Lecture Hall, City Museum, Leeds, 1.
First lecture in course designed to instruct projectionists and technicians in the principles of television broadcasting and large-screen television reproduction.
Enrolment fee for members 15s., non-members 25s.

BRITISH SOUND RECORDING ASSOCIATION

Date: January 23. Time: 7 p.m.
Held at: Royal Society of Arts, John Adam Street, London. W.C.2.
Lecture: Some Physiological Factors in Quality Appreciation.
By: E. A. Vetter.

Manchester Centre

Date: January 26. Time: 7.15 p.m.
Held at: The Engineers' Club, Albert Square, Manchester.
Lecture: Some Aspects of Tape Recording in the Home and Office.
By: E. R. Friedlander, M.Brit.I.R.E., D. R. Tasker and H. Turner.

Portsmouth Centre

Date: January 15. Time: 7.15 p.m.
Held at: Central Library, Guildhall, Portsmouth.
Members' Evening.

THE INSTITUTE OF NAVIGATION

Date: January 16. Time: 5 p.m.
Held at: The Royal Geographical Society, 1 Kensington Gore, London, S.W.7.
Lecture: Radar and Ice.
By: L. S. Le Page and A. L. P. Milwright.

THE INSTITUTE OF PHYSICS

North-Eastern Branch

Date: January 14. Time: 6.15 p.m.
Held at: University of Durham, King's College, Newcastle-upon-Tyne.
Lecture: Progress in Pure and Applied Ultrasonics.
By: Dr. E. G. Richardson, F.Inst.P.

Electronics Group

Date: January 13. Time: 5.30 p.m.
Held at: The Institute's House, 47 Belgrave Square, London, S.W.1.
Lecture: The Electronic Theory of Valency.
By: Professor C. A. Coulson, F.R.S.

Industrial Radiology Group

Date: January 16. Time: 6.30 p.m.
Held at: The Institutes House, 47 Belgrave Square, London, S.W.1.
Lecture: Radiation Protection.
(Joint meeting with the Hospital Physicists' Association.)

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings, unless otherwise stated, will be held at the Institution, commencing at 5.30 p.m.

Date: January 8. Time: 4.30 p.m.
Lecture: Nuclear Reactors and Applications.
By: Sir John Cockcroft, C.B.E., M.A., M.Sc. Tech., Ph.D., F.R.S.

Date: January 8. Time: 6 p.m.
Symposium of Papers on Nuclear Reactor Instrumentation.

Radio Section

Date: January 6.
Lecture: An Improved Scanning Electron Microscope for Opaque Specimens.
By: D. McMullan, M.A.
(Joint meeting with Measurements Section.)

Date: January 26.
Discussion: The Relative Merits of Harmonic and Intermodulation Measurements for Assessing Distortion in Audio Equipment.
Opened by: E. W. Berth-Jones.

Measurements Section

Date: January 20.
Discussion: Measurements of Magnetic Permeability.
Opened by: A. J. King, D.Sc., M.Sc.Tech.

Education Discussion Circle

Date: January 21. Time: 6 p.m.
Discussion: Some Difficulties in the Teaching of Electrical and Mechanical Resonance.
Opened by: C. T. Baldwin, M.A., and J. C. Oakden. M.A., M.Sc.Tech.

Merseyside and North Wales Centre

Date: January 5. Time: 6.30 p.m.
Held at: The Liverpool Royal Institution, Colquitt Street, Liverpool.
Lecture: Uses of Earthed Signal Conductors on Transmission Circuits.
By: W. Casson.

Date: January 14. Time: 6.45 p.m.
Held at: The Philharmonic Hall, Liverpool.
Faraday Lecture: Light from the Dark Ages or the Evolution of Electricity Supply.
By: A. R. Cooper.

North-Eastern Centre

Date: January 12. Time: 6.15 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-upon-Tyne.
Lecture: Uses of Earthed Signal Conductors on Transmission Circuits.
By: W. Casson.

North-Eastern Radio and Measurements Group

Date: January 5. Time: 6.15 p.m.
Held at: King's College, Newcastle-upon-Tyne.
Lecture: High-Gain D.C. Amplifiers.
By: K. Kandiah and D. E. Brown.

North Midland Centre

Date: January 6. Time: 6.30 p.m.
Held at: Offices of the British Electricity Authority, 1 Whitehall Road, Leeds.
Lecture: Electronic Telephone Exchanges.
By: T. H. Flowers, M.B.E., B.Sc.

Date: January 27. Time: 6.30 p.m.
Discussion: Lighting and Illumination in Electrical Engineering Courses.
Opened by: E. C. Walton, Ph.D., B.Eng.

North Midland Utilization Group

Date: January 20. Time: 6.30 p.m.
Held at: Offices of the British Electricity Authority, 1 Whitehall Road, Leeds.
Lecture: Electricity in Newspaper Printing.
By: A. T. Robertson.

North-Western Centre

Date: Janary 6. Time: 5.45 p.m.
Held at: The Engineers' Club, 17 Albert Square, Manchester, 2.
Lecture: The Characteristics and Control of Rectifier-Motor Variable-Speed Drive.
By: P. Bingley.

North-Western Radio Group

Date: January 7. Time: 6.30 p.m.
Held at: The Engineers' Club, 17 Albert Square, Manchester, 2.
Lecture: The Nervous System as a Communication Network.
By: J. A. V. Bates, M.A., M.B., B.Chir.

Northern Ireland Centre

Date: January 13. Time: 6.45 p.m.
Held at: The Presbyterian Hostel, Howard Street, Belfast.
Lecture: Technical Colleges and Education for the Electrical Industry.
By: H. L. Haslegrave, M.A., Ph.D., M.Sc.(Eng.).

South Midland Centre

Date: January 5. Time: 6 p.m.
Held at: The James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: Post-Graduate Activities in Electrical Engineering.
By: W. J. Gibbs, M.Sc.(Eng.), D. Edmundson, B.Sc., R. G. A. Dimmick, B.Sc., and G. S. C. Lucas, O.B.E.
(Joint meeting with the Education Discussion Circle.)

Date: January 29. (Time and place as above.)
Discussion: The Co-ordination of Technical and Practical Training.

South Midland Radio Group

Date: January 26. Time: 6 p.m.
Held at: James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: Electronic Telephone Exchanges.
By: T. H. Flowers, M.B.E., B.Sc.
(Joint meeting with the Birmingham Centre of the Institution of Post Office Electrical Engineers.)

Rugby Sub-Centre

Date: January 13. Time: 6.30 p.m.
Held at: Rugby College of Technology and Arts.
Lecture: Television Programme Origination and the Engineering Technique.
By: D. C. Birkinshaw, M.B.E., M.A.
(Joint meeting with the Rugby Students' Section.)

Southern Centre

Date: January 21. Time: 6.30 p.m.
Held at: The Polygon Hotel, Southampton.
Lecture: Post-Graduate Activities in Electrical Engineering.
By: W. J. Gibbs, M.Sc.(Eng.), D. Edmundson, B.Sc., R. G. A. Dimmick, B.Sc., and G. S. C. Lucas, O.B.E.

West Wales (Swansea) Sub-Centre

Date: January 29. Time: 6.30 p.m.
Held at: The Brangwyn Hall, Swansea.
Faraday Lecture: Light from the Dark Ages, or the Evolution of Electricity Supply.
By: A. R. Cooper.

Oxford District Meeting

Date: January 14. Time: 7 p.m.
Held at: The Southern Electricity Board, 37 George Street, Oxford.
Lecture: The Trend of Technical Education.
By: J. H. Brookes. M.A.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: January 27. Time: 5 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Lecture: Co-Axial Cables—Some Practical Aspects of their Design and Maintenance.
By: G. E. Rossiter, B.Sc.(Eng.), A.M.I.E.E.

Informal Meeting

Date: January 14. Time: 5 p.m.
Held at: Conference Room, 4th Floor, Waterloo Bridge House, S.E.1.
Lecture: Telephone Call Office Maintenance.
By: H. C. L. Grafton, A.M.I.E.E.

RADIO SOCIETY OF GREAT BRITAIN

Date: January 30. Time: 6.30 p.m.
Held at: Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Lecture: Single Side Band Transmissions.
By: R. H. Hammans.

SOCIETY OF INSTRUMENT TECHNOLOGY

Date: January 27. Time: 6.30 p.m.
Held at: Manson House, Portland Place, London, W.1.
Lecture: Instrumentation in the Paper Making Industry.
By: F. W. Hayward. B.Sc., A.Inst.P.

THE TELEVISION SOCIETY

Date: January 8. Time: 7 p.m.
Held at: The Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, W.C.2.
Lecture: An Introduction to the Sine-squared Pulse.
By: C. J. Hunt and E.W. Elliot.

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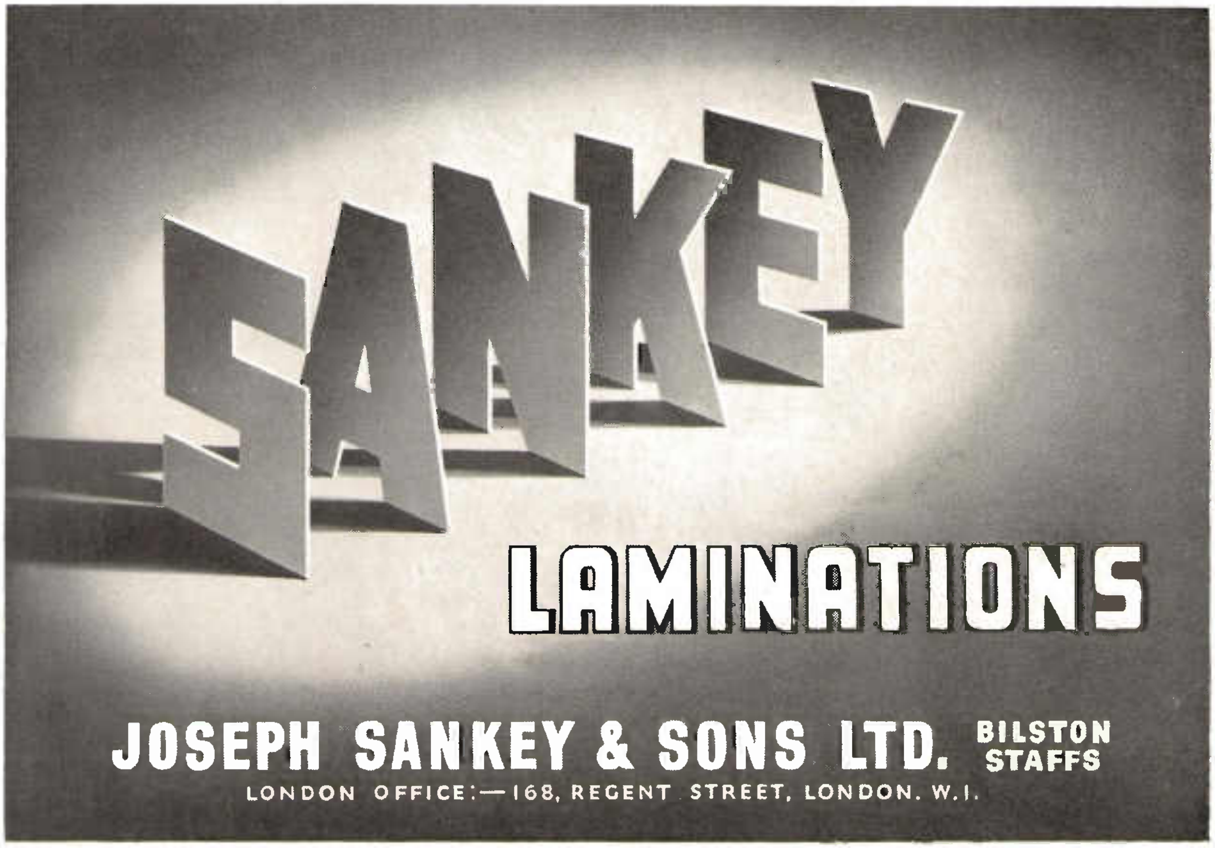
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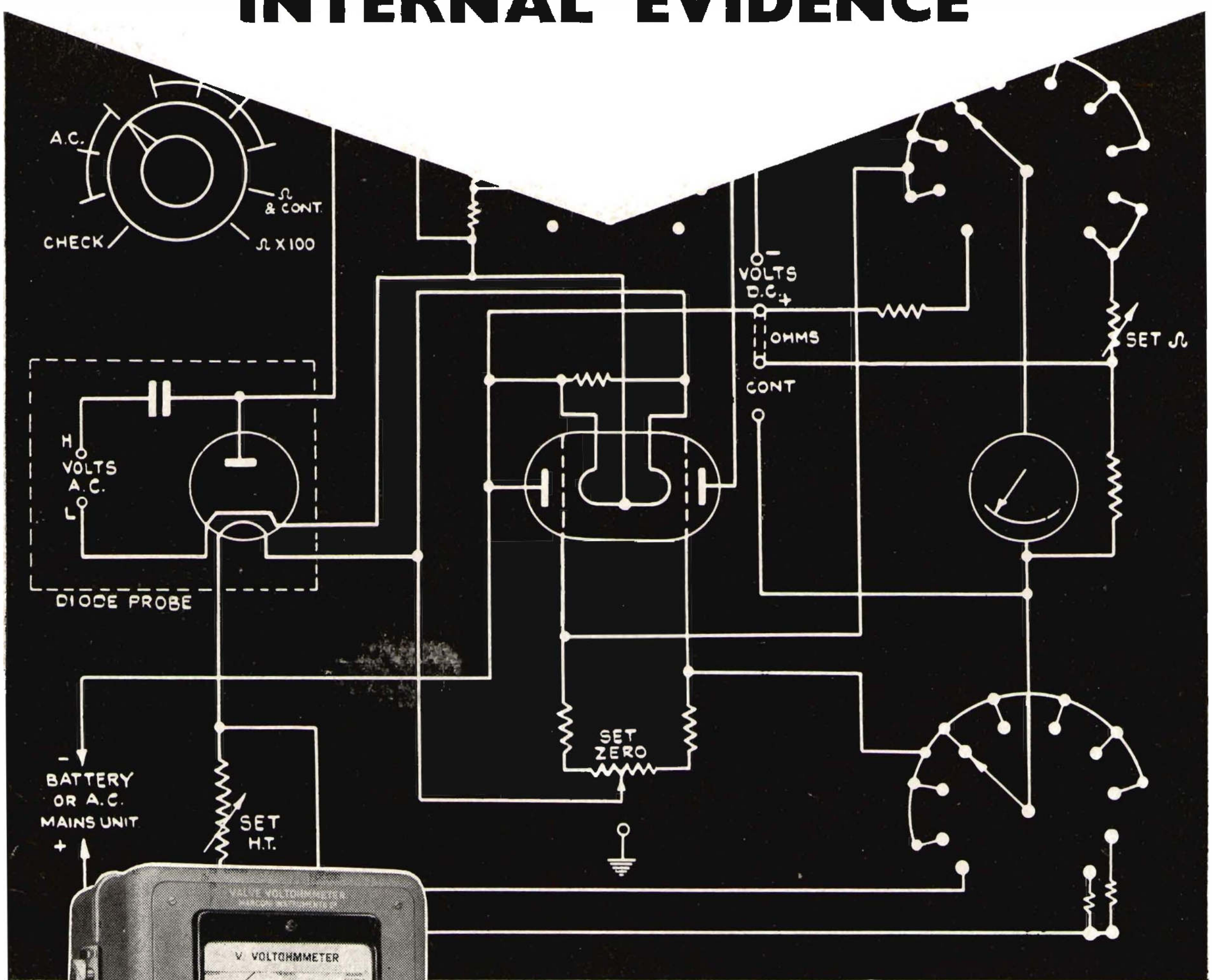

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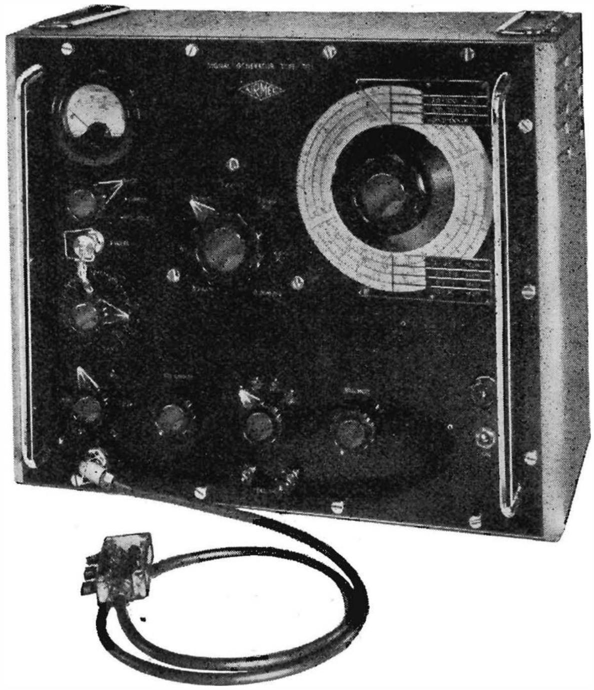
OUTPUT LEVEL Does the output level vary when changing frequency ? A constant output level is essential if measurements of receiver sensitivity or frequency response are to be made easily, quickly and accurately. The output signal from the Airmec H.F. Signal Generator Type 701 remains constant in amplitude $\pm$ 1 db over the whole frequency range from 30 kc/s to 30 Mc/s. Once the carrier level is set it may be forgotten.

FREQUENCY MODULATION *Does spurious Frequency Modulation occur with Amplitude Modulation ? This can be a source of continual trouble when dealing with narrow band-pass circuits. The employment of tuned buffer stages on all ranges of the Airmec Signal Generator Type 701 reduces the spurious F.M. occurring with A.M. to less than 5 kc/s at 60 per cent modulation at all frequencies.*



DISTORTION Is the waveform reasonably pure ? The disadvantages of a badly distorted waveform are obvious. The tuned buffer stages on the Airmec H.F. Signal Generator Type 701 enable a good waveform to be obtained at all frequencies.

OUTPUT AMPLITUDE *What values of signal can be obtained ? Accurately known output levels from several volts down to 1 microvolt are essential. The output signal from the 75 ohm step and slidewire attenuators of the Airmec H.F. Signal Generator Type 701 is continuously variable from 1.1 volt to 1 microvolt on open circuit. Furthermore, voltages between 5 and 20 are obtainable from a separate high impedance (300 ohm) output socket.*

EXTERNAL FIELD Is the external field low ? It is of little use providing accurate attenuators to reduce the signal to the value of a few microvolts if the external field from the generator is sufficient to swamp this signal. The external field of the Airmec H.F. Signal Generator Type 701 is negligible, being less than 1 microvolt per metre, at more than 1 ft. from the instrument.

PRICE AND DELIVERY *Are both the price and delivery reasonable ? The cost of the Airmec H.F. Signal Generator Type 701 is still only £135 and the delivery a few weeks.*

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A.B. Metal Products Ltd. proudly announce that they have been granted by the Clarostat Manufacturing Company Inc., Dover, New Hampshire, U.S.A., the sole manufacturing rights of the world-famous range of Clarostat Controls and Resistors.

Clarostat Controls and Resistors are known throughout the world for dependability and exceptional performance. Every control is designed and built to the very highest standard, and the wide range includes components which have not previously been available in this country.

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Only a brief outline of the **Clarostat** range can be given in this present announcement, but further details will be issued as soon as possible, and a catalogue will be made available shortly.

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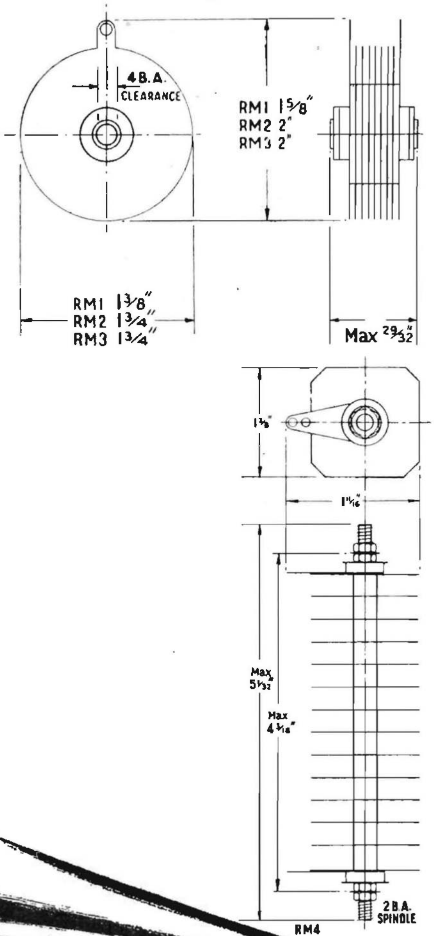

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Maximum output current (mean)	60mA	30mA	100mA	60mA	120mA	90mA	275mA	250mA	125mA
Maximum input voltage (r.m.s.)	125V		125V		125V		250V		
Maximum peak inverse voltage	350V		350V		350V		700V		
Max. instantaneous peak current	Unlimited		Unlimited		Unlimited		Unlimited		
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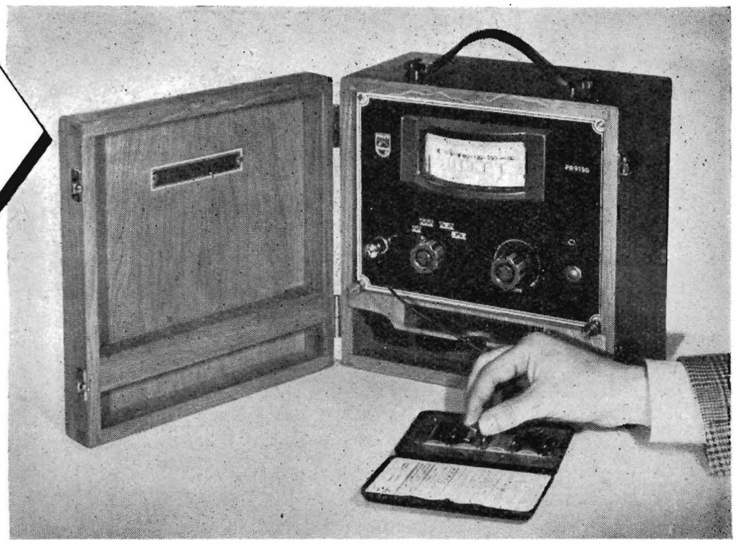

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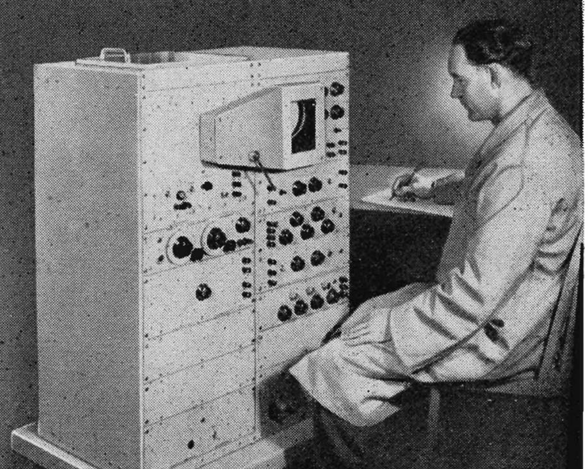

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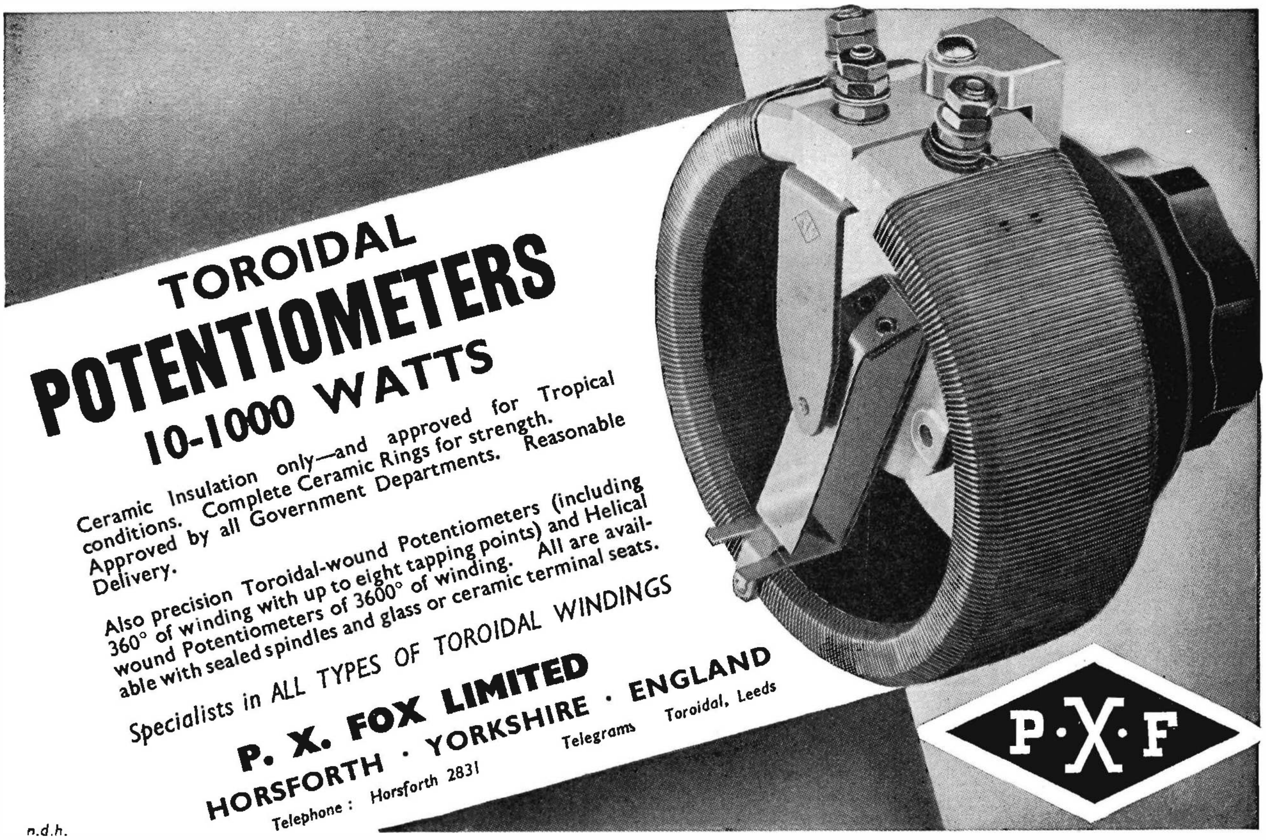

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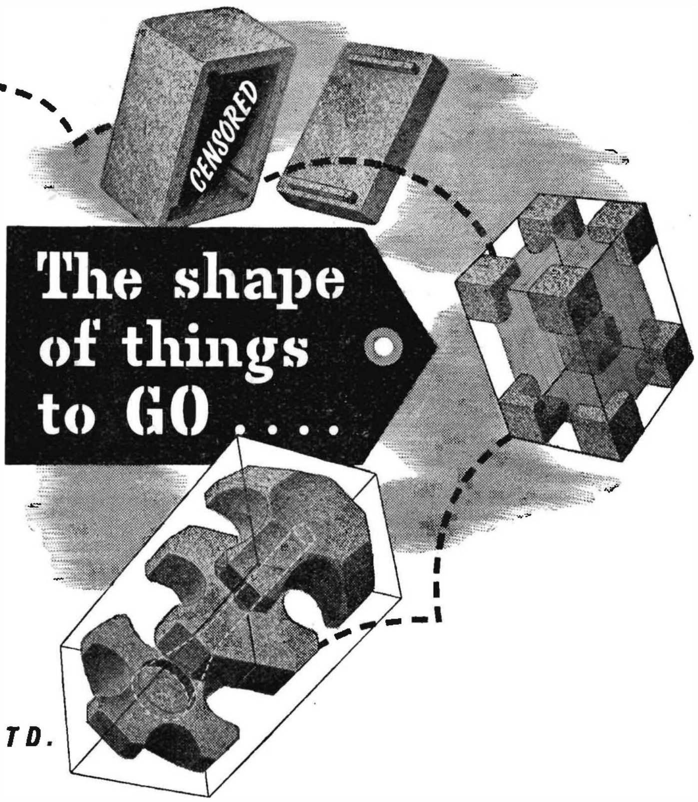

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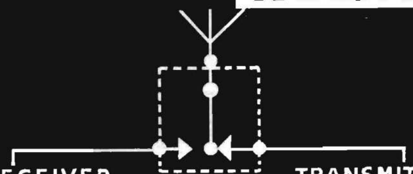

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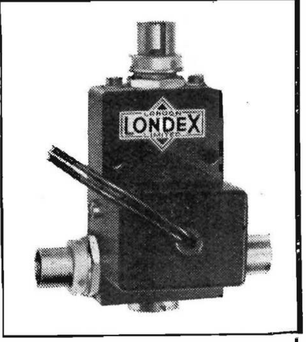

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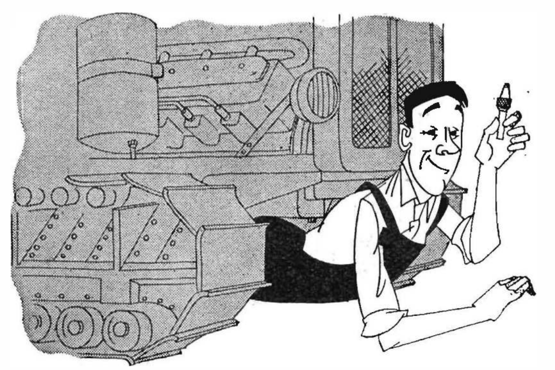

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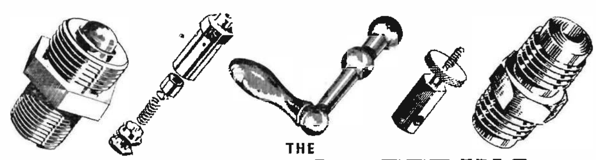

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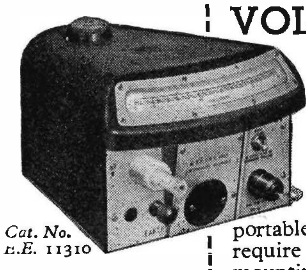

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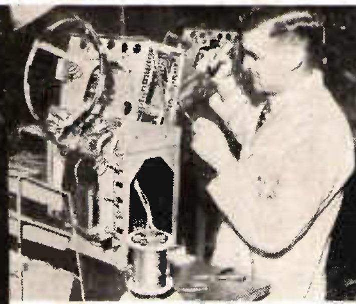

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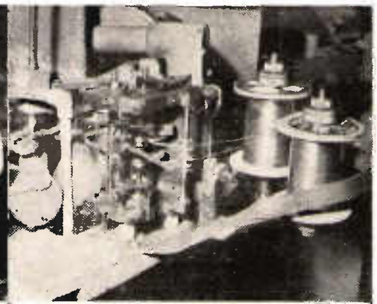

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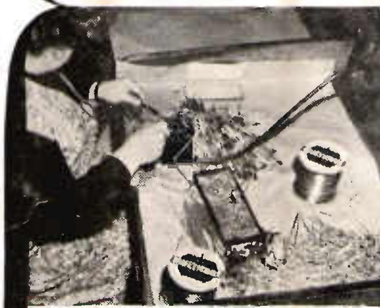

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TELEPHONES Automatic Exchanges each having more than a million soldered joints are made to last a lifetime with ERSIN MULTICORE SOLDER.

7 LB. REELS FOR FACTORIES

Ersin Multicore Solder is the only solder containing 3 cores of Ersin Flux, a high-grade rosin which has been subjected to a complex chemical process to increase its fluxing action, whilst still retaining the non-corrosive properties.

Ersin Multicore Solder is made as standard for factory use in 6 alloys and 9 gauges, and is supplied in nominal 7 lb. reels. Other alloys and gauges can be supplied to special order. Prices on application.

SIZE 1—5/- CARTONS (SUBJECT)

Ersin Multicore Solder is made in 4 specifications for radio and electrical use.

Catalogue Ref. No.	Alloy Tin/Lead	S.W.G.	Approx. Length per carton
C. 16014	60/40	14	18 feet
C. 16018	60/40	18	47 feet
C. 14013	40/60	13	16 feet
C. 14016	40/60	16	34 feet

SERVICE ENGINEER'S 1 LB. REEL

An economy pack for Service Engineers and Workshops using fair quantities of solder. 1 lb. reel containing approximately 167 feet of 18 s.w.g. 50/50 alloy packed in an attractive yellow and black carton.

PRICE 15/- SUBJECT. CAT. REF. NO. R. 5018

COMSOL ALLOY

By arrangement with Johnson Matthey & Co. Ltd. of Hatton Garden, Ersin Multicore Solder is now available in Silver/Tin/Lead Comsol alloy. Ersin Multicore Comsol alloy has a solidus melting point of 296°C. This is 113°C. above the solidus melting point of the usual tin/lead alloys.

ARAX MULTICORE SOLDER

contains 2 cores of non-rosin Arax Flux; will solder practically any metal instantly, including blued spring steel. Flux residue is easily removed with water. Supplied as standard in 3 alloys, 9 gauges, on 7 lb. reels for Manufacturers. Available also in Size 8 cartons (5/- subject).

NEW PUBLICATIONS

Copies of the following publications are available free of charge to manufacturers:

MANUFACTURERS TECHNICAL SUMMARY

(Ref. M.52) giving full details of all Multicore products, useful technical data, packing specifications, etc.

CONSIDERATIONS OF SOLDERING TECHNIQUE

(Ref. M.53) a transcription of a Technical Paper delivered to the Australian I.R.E. Convention in Sydney—containing comparisons of soldering techniques from information supplied by leading Radio, TV and Electronic manufacturers in Britain.

The above publications will also be sent to Radio enthusiasts on receipt of a stamped addressed envelope.

Ersin Multicore Solder

MULTICORE SOLDERS LTD.

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