ELECTRONICS IN INDUSTRY SUPPLEMENT

Electronic Engineering

APRIL 1952

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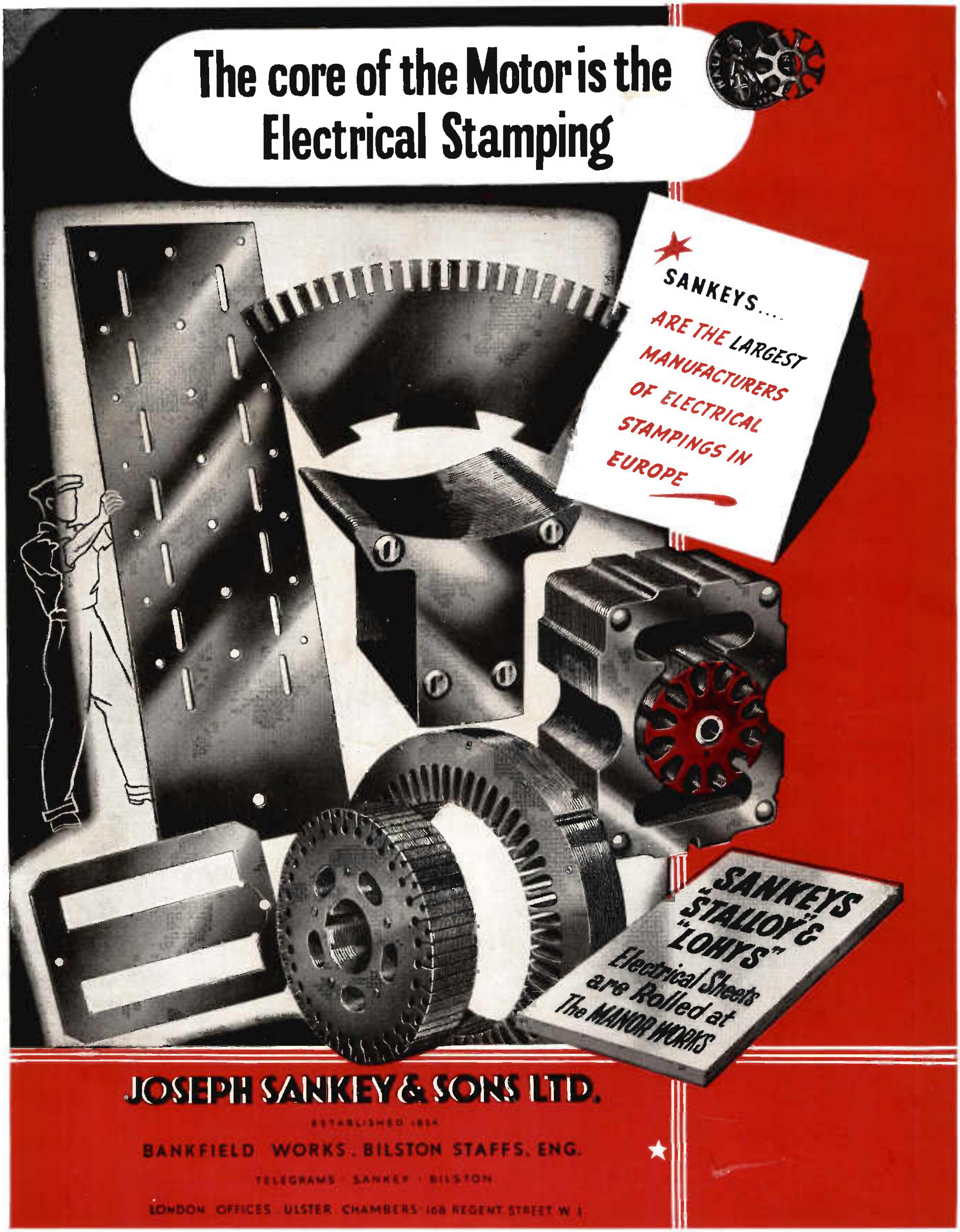
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CLASSIFIED ANNOUNCEMENTS

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

OFFICIAL APPOINTMENTS

ADMIRALTY. Royal Naval Scientific Service. Vacancies for Senior Scientific Officers (S.S.O.), Scientific Officers (S.O.), Experimental Officers (E.O.), Assistant Experimental Officers (A.E.O.) in the London area and Gloucestershire. Candidates should be (1) Electronic Engineers or Physicists interested in any of the following: modern communication systems, pulse technique, all forms of recording, high speed data handling, electronic computing and similar techniques. (2) Mathematicians with interests in statistics, probability and automatic computing (S.O.'s and S.S.O.'s only). Candidates must be British subjects and for the S.S.O. and S.O. posts possess a first or second class Honours Degree in Physics, Engineering or Mathematics, or alternatively have high professional attainments such as corporate membership of an appropriate professional institution with suitable experience and responsibility. Minimum age: S.S.O.—26 years and not less than three years' approved experience, S.O.—21 years. London salary scales (men): S.S.O., £750-£950 per annum; S.O., £400-£650 per annum. The S.S.O. and S.O. appointments carry superannuation benefits under F.S.S.U. For E.O. and A.E.O. posts, candidates should possess one of the following qualifications: (a) University Degree in Science, Engineering or Mathematics; (b) Graduate membership of an appropriate professional institution; (c) Higher National Certificate; (d) the final certificate of a five-year grouped course in a relevant subject at the City and Guilds of London Institute or any comparable institution; (e) Higher School Certificate with Mathematics or Science as a principal subject or an equivalent qualification. Minimum age: E.O.—26 years; A.E.O.—17½ years. London salary scales (men) are: E.O. £575-£725 per annum, and A.E.O. £250-£535 per annum. In all cases rates for women and posts in the provinces are somewhat lower. Starting salaries above the minimum may be granted according to age and experience. Opportunities to compete for permanent posts will occur from time to time. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register, K, 26 King Street, London, S.W.1, quoting A7/52/A. W 2481

APPLICATIONS are invited by the Ministry of Supply from Electrical Engineers and Physicists for work on out-of-door instrumentation at experimental and development establishments near Southend and Carlisle. Candidates must possess a minimum qualification a Higher School Certificate with Physics as a main subject but other qualifications e.g. Higher National Certificate in Electrical Engineering may be an advantage. Experience in design of electronic apparatus and interest in technical photography is desirable. Salary will be assessed according to age, qualifications and experience within the range: Experimental Officer (minimum age normally 26) £545 to £695. Assistant Experimental Officer £240 (at age 18) to £505. Rates for women somewhat lower. The posts are unestablished. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register, Almack House, 28 King Street, S.W.1, quoting D63/52A. Closing date 11th April, 1952. W 2530

APPLICATIONS are invited by the Ministry of Supply for the following posts at the Tropical Testing Establishment, Port Harcourt, Nigeria. Senior Scientific Officer. Post 1 Physicist or Electrical Engineer to lead a group of physicist and engineers studying the effects of tropical conditions on service materials and equipment. Candidates should have experience in one or more of the following fields electrical or mechanical testing of materials, or electronics. Some knowledge of statistical analysis or meteorology would be an advantage (Ref. A36/52/A). Post 2 Chemist or Biologist to lead a group of chemists and biologists studying the effect of tropical condition on service materials and equipment. Knowledge and/or experience of physical chemistry and mycology is desired (Ref. F96/52/A). Candidates for posts 1 and 2 must be over 26 years of age and should have a 1st or 2nd class Honours Degree in the appropriate subject or equivalent qualification with at least 3 years post-graduate, research experience. Experimental Officer or Assistant Experimental Officer (2) Candidates should have at least Higher School Certificate or equivalent qualification in science, including Physics, with experience in Electrical or Mechanical Engineering. Higher qualifications may be an advantage. For one post a mechanical engineer with some knowledge of physics is desired. For the other, candidates should have a good knowledge of physics, preferably with some experience in one or more of the following fields: Electrical or tensile testing of materials including textiles and plastics, or meteorology (Ref. A37/52/A). The posts are unestablished and open to men only. Appointments are for an initial tour of 18 months but further tours may be arranged by mutual agreement. Consideration will be given to further employment in U.K. at the end of service in W. Africa. Salaries will be assessed according to age, qualifications, and experience within the following ranges: Senior Scientific Officer—£750 to £950 p.a. Experimental Officer (minimum age normally 26)—£575 to £725 p.a. Assistant Experimental Officer—£250 (at age 18) to £535 p.a. The posts are unestablished but the Senior Scientific Officer posts carry benefits under F.S.S.U. Foreign Service allowance ranging from £200 to £500 is also payable, according to marital status, accommodation is provided free. Subject to certain conditions, passages by sea from the U.K. can be provided at public expense for families. A detailed explanation will be given to candidates selected for interview. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting appropriate reference number. Closing date 11th April, 1952. W 2532

ASSISTANT (Scientific) Class: The Civil Service Commissioners give notice than an Open Competition for pensionable appointment to the basic grade will be held during 1952. Interviews will be held throughout the year, but a closing date for the receipt of applications earlier than December, 1952, may eventually be announced either for the competition as a whole or in one or more subjects. Successful candidates may expect early appointments. Candidates must be at least 17½ and under 26 years of age on 1st January, 1952, with extension for regular service in H.M. Forces but candidates over 26 with specialised experience may be admitted. All candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects: (i) Engineering and physical sciences. (ii) Chemistry, bio-chemistry and metallurgy. (iii) Biological Sciences. (iv) General (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing). Salary according to age up to 25: £236 10s. at 18 to £363 (men) or £330 (women) at 25 to £500 10s. (men) or £418 (women); somewhat less in the provinces. Opportunities for promotion. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S 59/52. Completed application forms should be returned as soon as possible. W 2557

ASSISTANT (Scientific) Class: The Civil Service Commissioners give notice that an Open Competition for pensionable appointment to the basic grade will be held during 1952. Interviews will be held throughout the year, but a closing date for the receipt of applications earlier than December, 1952, may eventually be announced either for the competition as a whole or in one or more subjects. Successful candidates may expect early appointments. Candidates must be at least 17½ and under 26 years of age on 1st January, 1952, with extension for regular service in H.M. Forces, but other candidates over 26 with specialised experience may be admitted. All candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects: (i) Engineering and physical sciences. (ii) Chemistry, bio-chemistry and metallurgy. (iii) Biological Sciences. (iv) General (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing). Salary according to age up to 25. £215 at 18 to £330 (men) or £300 (women) at 25 to £455 (men) or £380 (women); somewhat less in the provinces. Opportunities for promotion. Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S 59/52. Complete application forms should be returned as soon as possible. W 2493

ELECTRICAL ENGINEERS and Physicists are invited by the Ministry of Supply to apply for the following posts in the Scientific Officer class at the Instrument and Photographic Department of the Royal Aircraft Establishment, Farnborough, Hants. 1, For the assessment of analogue computor and servo-mechanism techniques and the development of precision equipment in that field for use in aircraft (Ref. No. A347/51/A). 2, For the analysis of the complex dynamical problems arising in automatic control of aircraft and for research upon methods of control. An interest in aerodynamics, particularly stability and control is desirable and candidates must be willing to fly as an observer. Some experience in research or development of light electrical or electronic equipment, or servo systems, and a knowledge of electronics would be advantageous (Ref. No. A348/51/A). 3, For research and development work in connexion with gyroscopic and allied instruments. Some experience in experimental and design work is desirable and a practical knowledge of electronics would be an advantage. The work offers considerable scope for inventive ability (Ref. No. A349/51/A). Candidates should have a 1st or 2nd class Honours Degree or equivalent qualification in Physics or Electrical Engineering. Applicants for the senior grade must be at least 26 years of age and should have at least 3 years post-graduate research experience. Salaries will be assessed according to age, qualifications and experience within the inclusive ranges. Senior Scientific Officer £781-£980. Scientific Officer £417-£675. Rates for women somewhat lower. The posts are unestablished but carry benefits under F.S.S.U. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1, quoting the appropriate reference number. Closing date 29th April, 1952. W 2522

ELECTRICAL ENGINEERS are invited by the Ministry of Supply to apply for the following Principal Scientific Officer posts at a Research Establishment south-east of London: (1) To be responsible for the engineering aspects of airborne electronic equipment. Experience of the design of radio and/or radar equipment and in the engineering of development prototypes for production is essential, and knowledge of aerial design and of airborne equipment would be an advantage. Ref. D42/52A. (2) For research and development in V.H.F., and U.H.F., transmission and reception. Experience in radio-communication and a knowledge of transmitter design is essential. Previous experience in leading a team of scientists in the execution of field trials would be of value. Ref. D43/52A. (3) With experience in the design of electronic equipment. A sound knowledge of physical principles and electronic applications to physics problems would be an advantage. Ref. D44/52A. (4) For design and development work in a wide field of electronic instruments. Experience in the design of radio receivers and transmitters and/or in the handling of high speed transients would be of value. Ref. D45/52A. Candidates, who should be at least 31 years of age, should have a 1st or 2nd class Honours Degree in Electrical Engineering or equivalent qualification. Salary will be assessed according to age, qualifications and experience within the range £960 to £1,295. Rates for women somewhat lower. The posts are unestablished but carry benefits under F.S.S.U. Application forms obtainable from Technical and Scientific Register K, Almack House, 26 King Street, S.W.1, quoting appropriate reference number. Closing date 15th April, 1952. W 2497

MINISTRY OF SUPPLY requires Technical Authors for Establishments at Chessington, Malvern and Farnborough. Successful candidates will be graded Engineer III or Technical grade I, according to age, qualifications and experience. Qualifications: British, of British parentage; regular engineering apprenticeship; Degree in engineering or physics or corporate membership of one of the Institutions of Civil, Mechanical or Electrical Engineers or exempting qualifications. Alternatively, candidates with good practical experience in a responsible technical position and preferably holding Higher National Certificate or equivalent qualification will be considered. Candidates must have had either research or development experience of the apparatus and techniques in industry or technical responsibility in the Services on the operation and servicing of equipments described below. Experience in writing or editing technical publications an advantage. Duties: Preparation of official instructional publications on the theoretical and practical (including servicing) aspects of airborne and ground centimetric radar or radio communications equipment. Salaries: Engineer grade—£585 (linked to age 26)-£880 p.a. (intermediate rate—slightly less in provinces). Not established, periodical competitions for established pensionable posts. Technical grade—within the range £660-£805 p.a. (intermediate rate—slightly less in the provinces). Not established, opportunities for established pensionable posts may arise. Application forms from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1. (Quoting D375/51A.) Closing date 11th April, 1952. W 2529

MINISTRY OF SUPPLY requires Engineer Technical Grade I (Technical Author) for an Establishment at Chessington, Surrey. Qualifications: British, of British parentage; regular engineering apprenticeship or equivalent training, preferably on light electrical apparatus; technical responsibility in industry or in the Services on aircraft electrical components or installations: experience in writing or editing technical publications; sound knowledge of electronics; Higher National Certificate or equivalent in electrical engineering advantageous. Duties: Preparation of official instructional handbooks and circuit diagrams on theoretical and practical (including servicing) aspects of airborne and ground electrical equipment or on complete electrical installations in aircraft; Salary: Within the range £660-£805 p.a. Not established, opportunities for established pensionable posts may arise. Application forms from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1. (Quoting D.376/51A.) Closing date 11th April, 1952. W 2531

REQUIRED by the Ministry of Supply Physicists for the following posts in the Scientific Officer class at a Research Establishment in Cambridgeshire. Senior Scientific Officers. 1, With some engineering or metallurgical experience for investigations of a fundamental nature relating to armour penetration problems (Ref. A51/52/A). 2, With mathematical ability and some knowledge of Thermodynamics for work on the mechanism of damage by small calibre shell (Ref. A52/52/A). Scientific Officers (3 posts) with experience of electronics for work in connexion with high speed photography (Ref. A53/52/A). Candidates, should have a first or second class Honours Degree in Physics or equivalent qualification. For the senior grade candidates should be at least 26 years of age with a minimum of three years post-graduate research experience. Salary will be assessed according to age, qualifications and experience within the inclusive ranges: Senior Scientific Officer—£781 to £980 p.a. Scientific Officer—£417 to £675 p.a. Rates for women somewhat lower. The posts are unestablished but carry F.S.S.U. benefits. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1, quoting appropriate reference number. Closing date 11th April, 1952. W 2544

UNIVERSITY COLLEGE, Southampton. Department of Electronics. The Department of Electronics (Professor E. E. Zepler) gives an advanced course at Honours Degree standard in Electronics. The course is full-time for one academic year and the college grants a diploma by examination to students who successfully complete the course. Entry qualification is a University Degree in Physics or Electrical Engineering, or its equivalent. The sixth of these courses will commence in October, 1952, and application for admission should be made now to the Academic Registrar, from whom further details be obtained. W 1416

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.

A LARGE Engineering Company in the East London area require the services of an Electrical Engineer with specialised practical and theoretical knowledge of mass production resistance welding. Applicants must be able to design equipment, have full knowledge of electronic circuits and practical mechanical experience. This is a staff position and carries a high salary. Applicants should give full details of experience, age, etc., to Box K.969 A.K. Advg., 212a Shaftesbury Avenue, London, W.C.2. W 2558

A LEADING COMPANY in the Radio and Electronic Industry setting up a new laboratory in the West London Area has vacancies for Electronic Engineers, Draughtsmen, and Model Markers of all grades. Applicants for these vacancies should give full details of qualifications and experience and should state salary required. Apply Box No. W 2556.

A SENIOR PHYSICIST required for research and development work on mica and ceramic capacitors, and other similar new components and their raw materials. Applicants should have held a responsible position in this field at not less than £800 per annum, and should have a knowledge of the chemistry of the product, and have had the experience of control of investigation at executive level. The post offers scope to a qualified man with imagination and initiative. Please write giving fullest particulars, in confidence, of experience, qualifications, salary earned, etc., to General Manager, London Electrical Manufacturing Co., Ltd., Beavor Lane, Hammersmith, W.6. W 1432

A VACANCY exists in the Luton Laboratories of the English Electric Co., Ltd., for an Engineer with a Degree or H.N.C. and experience in small servo-mechanisms for development work on analogue computing devices, involving A.C. and D.C. techniques. Please apply quoting Ref. 862C to Central Personnel Services, English Electric Co., Ltd., 24/30 Gillingham Street, London, S.W.1. W 2551

AN ELECTRONIC TECHNICIAN is required by St. Bartholomew's Hospital, London, E.C.1. Duties involve servicing, planning, construction and testing of electronic equipment used in radioactive and radiation assaying and in other applications to medicine. Salary according to experience in the Medical Laboratory Technicians scale of £410 x £15 (3) x £20 (1) to £475, plus London Weighting. Applications, together with references to The Clerk to the Governors. W 2547

APPLICATIONS are invited for the post of Electronic Development Engineer by a Company developing and manufacturing Electronic Instruments. Experience in this field essential. Please apply giving details of technical background, etc., to Furzehill Laboratories, Ltd., Boreham Wood, Herts., through local Employment Exchange. W 1449

APPLICATIONS are invited by an expanding Electronic Engineering Company in Buckinghamshire for the following vacancies: Technical Assistants with Engineering Degree and experience of electronic equipment. Senior Engineer with B.Sc. Engineering in Electronic subjects, preferably telecommunication, and at least 3 years experience of electronic equipment. Please write, giving full details and salary required, to the Personnel Officer, Airmec Laboratories Ltd., High Wycombe. W 2508

APPLICATIONS are invited for the post of Chief Inspector to the Cheltenham Research Laboratories of Furzehill Laboratories Ltd. Applicants should have a thorough experience of electrical and electronic work and be fully conversant with the general requirements of A.I.D. and A.R.B. procedure. Engineering qualifications should preferably be to degree standard. Housing accommodation available to the selected applicant if required. Write, stating age, qualifications and salary required to—Chief Engineer, Furzehill Laboratories Ltd., Shenley Road, Boreham Wood, Herts. W 2535

APPLIED MATHEMATICIANS required. Applications from Graduates (male and female) are invited for work of national importance. Knowledge of servo or telecommunication theory desirable but not essential. Apply with full details of age, experience and salary required to the Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middlesex. W 2523

A WELL-KNOWN Midland Company requires an H.F. Heater Applications Engineer for test work on samples and the design of applicators. Men with metallurgical knowledge and at least H.N.C. should apply, giving full details of qualifications and experience, quoting Reference HFH to Box No. W 2566.

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

BRITISH TELECOMMUNICATIONS Research Ltd., associated with Automatic Telephone and Electric Co., Ltd., and British Insulated Callender's Cables Ltd., require an Engineer in their Patents Department for general duties associated with line and radio telecommunications equipment and systems. An attractive salary will be offered to suitably qualified candidate. The position is permanent and covered by the superannuation scheme. 5-day week. Application should be made to the Director of Research, British Telecommunications Research Ltd., Taplow Court, Bucks, giving full details of qualifications and experience. W 2527

BUYER required for Electrical Trade in Surbiton, Surrey area. Previous experience essential. Five day week with Pension and Bonus Scheme in operation. Salary according to experience and qualifications. Write giving full details. Box No. W 2569.

CABLE AND WIRELESS LTD. have vacancies for Technical Assistants in their London Radio Research and Development Laboratories. Applicants should possess Ordinary National (Telecommunications) or City and Guilds Radio II Certificates, with some radio mechanic experience. Pensionable appointments. Commencing salary according to age and experience. Write giving full details to Staff Manager, Electra House, Victoria Embankment, London, W.C.2. W 2564

CROMPTON PARKINSON Limited, have vacancies for the following. (1) A Graduate Physicist or Electrical Engineer with good Honours Degree to work in Lamp Development Laboratory, Guiseley, on general lamp problems. (2) A Science Graduate with a leaning towards practical problems to work on technical control in lamp works (filament and discharge) at Doncaster. Applicants with or without experience will be considered. Good prospects for men wishing to make a career in industry. Send full particulars of training and practical experience, if any, to GLG/A, Crompton Parkinson Ltd., Guiseley, Nr. Leeds, Yorkshire. W 2526

CHIEF INSPECTOR required for Electrical Engineering Works employing some 600 hands and specialising in Coils, Solenoids, Amplifiers and General Electronics. Must be able to organise and control detailed inspection and testing of semi-mass-produced, high quality in-

CLASSIFIED ANNOUNCEMENTS
continued on page 4

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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.

dustrial electro-magnetic and electronic gear. House available. Good salary and prospects. Write in confidence giving full particulars to Box No. W 2524.

DESIGN DRAUGHTSMAN required by Electronic Engineering Company. H.N.C. in Mechanical Engineering an advantage together with several years experience in Mechanical Design of Electronic Instruments. Please apply to Furzehill Laboratories, Ltd., Boreham Wood, Herts., through local Employment Exchange. W 1450

DESIGNERS and draughtsmen with experience in electronic or light mechanical engineering are required by the G.E.C. Research Laboratories, Wembley, Middlesex, for work at Stanmore. Vacancies exist for seniors with good academic qualifications and also for juniors. Excellent and interesting openings with good prospects. Apply to the Staff Manager (Ref. GBLC/550), stating age and record. Box No. W 2542.

DEVELOPMENT ENGINEER (Electronics) required for new radio communication equipment. London area. Practical experience essential. Ample scope for advancement. Apply in writing, giving age, previous experience and salary required to Box No. W 1443.

DEVELOPMENT ENGINEERS required in the Radio Component Laboratory of the Plessey Company Limited. Applicants for these positions should preferably have a Degree in Engineering or Physics, or Higher National Certificate, and should have experience in the development of light Electro Mechanical Mechanisms. The positions give the right of entry into the Company's pension fund and life assurance scheme after a probationary period and offer excellent opportunities of promotion. Applications should be made in writing, stating full details, to the Personnel Manager. The Plessey Co., Ltd., Ilford, Essex. W 2510

E. K. COLE LIMITED (Malmesbury Division), invite applications from Electronic Engineers for permanent posts in Development Laboratories engaged on long-term projects involving the following techniques: 1. Pulse Generations and Transmission. 2. Servo Mechanisms. 3. Centimetric and V.H.F. Systems. 4. Video and Feedback Amplifiers. 5. V.H.F. Transmission and Reception. 6. Electronics as applied to Atomic Physics. There are vacancies in the Senior Engineer, Engineer and Junior Grades. Candidates should have at least 3 years' industrial experience in the above types of work, together with educational qualifications equivalent to A.M.I.E.E. examination standard. Commencing salary and status will be commensurate with qualifications and experience. Excellent opportunities for advancement are offered with entry into Pension Scheme after a period of service. Forms of application may be obtained from Personnel Manager, Ekco Works, Malmesbury, Wilts. W 2321

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

ELECTRICAL ENGINEER required experienced in high frequency heating and its application to furniture production. Excellent remuneration for the right man. Apply—Beautility Furniture Ltd., Angel Road, Edmonton, N.18. W 1441

ELECTRICAL ENGINEERS. Age 25-30 with Degree or Higher National Certificate and practical experience in Servos, Electronics or Telecommunications, required for development work on low power servo systems. Apply with full particulars to Manager, Engineering Department and Labour, Vickers-Armstrongs, Ltd., Crayford, Kent. W 2563

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 2528

ELECTRONIC Development Engineer required for work on industrial electronic control systems. Applicant should have a Degree or equivalent in physics or electrical engineering and practical knowledge of machine control techniques. Some experience on radiation and capacitive methods of mass measurement an advantage. Minimum salary £600 per annum and upwards according to qualifications. South Manchester district. Rep'y giving full details of education, qualifications, experience, age, etc., to Box No. W 1428.

ELECTRONICS. Nelson Research Laboratories, English Electric Company, Limited, Stafford, have vacancies for men with Higher National Certificate or with experience in radio, radar or general electronics, for work on high speed electronic computing machines. The appointments will be in the London area for an initial period of at least one year. Write giving full details to Westminster Employment Exchange, Chadwick Street, London, S.W.1. To ensure that your application is promptly passed to the Company, please mark it English Electric 963. W 2554

ELECTRONIC ASSISTANT required for laboratory at Cambridge. Duties will include the wiring and testing of circuits, and the use of hand machine tools in the making of the mechanical parts of research apparatus designed in the laboratory. Salary according to qualifications and experience. £250-£300 p.a. Box No. W 1433.

ELECTRONIC COMPUTING Section to be started will require Leader (Honours Degree) and Assistants (Degree or H.N.C.). Apply Employment Manager, Vickers-Armstrongs Ltd. (Aircraft Section), Weybridge, Surrey. W 2520

ELECTRONIC ENGINEER, with good theoretical background to Higher National Certificate standard and with practical experience in use of valves in audio and radio frequency circuits, is required in the Valve Life Testing Laboratory at the G.E.C. Research Laboratories, Wembley, Middlesex. Apply to the Staff Manager (Ref. GBLC/O/568) stating age and record. W 2518

ELECTRONIC ENGINEERS required for design work on aircraft electronic systems. Apply Employment Manager. Vickers-Armstrongs Ltd. (Aircraft Section), Weybridge. Surrey. W 2505

ELECTRONIC ENGINEERS with practical experience in sound recording equipment required for testing and servicing. London area. Excellent prospects. Apply in writing, giving age, previous experience and salary required to Box No. W 1444.

ELECTRONIC ENGINEERS for development work with substantial Birmingham Company. Honours Degree in Electrical Engineering or Physics with industrial experience in circuitary and instrument design essential and some practical experience in the application of optics would be an advantage. Five-day week. Staff pension scheme. Excellent working conditions and sound promotion prospects. Initial salary fully commensurate with qualifications and experience. Applications, which will be treated in confidence, should state full particulars of education and experience. Box No. W 2536.

ELECTRONIC ENGINEERS required for development work in the Gloucestershire area. Good academic qualifications and apprenticeship. Experience in one or more of the following desirable: Control systems, D.C. Amplifiers, Computing devices. Video Circuits, Microwave Techniques. Apply with full details of qualifications, age and salary required to Box AC 68965, Samson Clarks, 57/61 Mortimer Street, W.1. W 2457

ELECTRONIC RESEARCH and Development Engineers with 1st or 2nd class Honours Degree in Physics or Electrical Engineering required by old established firm in North West London. Experience should enable applicants to carry out research and/or design complete electronic measuring and control equipment for precision industrial instruments. A very wide range of electronic problems is involved. Age approximately 25-30 years. Salary in accordance with age, qualifications and experience. Please apply Box No. W 1451.

E.M.I. ENGINEERING Development Limited, have a number of vacancies for engineers and senior engineers on interesting development work in various electronic engineering projects. The posts are for permanent pensionable staff and offer good prospects. Qualifications a Degree in Physics or Engineering or equivalent, together with several years design or specialised experience in the following fields: (a) L.F. Equipment (b) Television Equipment (c) Microwave Techniques (d) Pulse Techniques (e) Servo Mechanisms (f) Test Gear Design (g) Inspection. Applicants should write giving full details of experience and type of work required, and quote ED/33, to: Personnel Department, E.M.I. Engineering Development Limited, Blyth Road, Hayes, Middx. W 2517

ENGINEER required to initiate and maintain small scale production of specialised miniature valves. Applicants must have had considerable experience in a technical capacity on valve development and production. Attractive salary will be paid to the successful applicant. Initial applications treated in strictest confidence. Write, giving age, experience, etc., to Box No. W 2506.

ENGINEER, experienced in the design of complex light mechanisms required for interesting development work. Qualifications: Degree or Higher National Certificate in Engineering. Physics or Mathematics with some experience of two of the following: Hydraulics, Gyro-mechanisms, Stressing Metallurgy, Optics or Electronics. The post is permanent, pensionable and offers good starting salary and prospects. Applicants should write, giving full details to: Personnel Department (ED/68). E.M.I. Engineering Development Ltd., Hayes, Middx. W 2514

ENGINEER required (25-35 years) with a Degree in Electrical Engineering or Physics, and experienced in the Electronic Engineering field, to be trained as a technical representative for a nationally known company, over territory South Yorkshire to Scotland, commensurate salary. Box No. W 2549.

ENGINEER required for work on vibration and noise problems. Duties would include the development and active use of Electronic Measuring Apparatus for this work. Applicant should have Honours Degree in Engineering or equivalent. Apply in writing giving details of qualification and past experience to: The Manager, Electronics Engineering Dept., The British Thomson-Houston Co., Ltd., Rugby. W 2541

ENGINEERS and Physicists with experience in the following fields are required by the G.E.C. at the Stanmore Laboratories. (a) servo-mechanisms (b) microwave aerials, transmitters or receivers (c) small mechanisms (d) electronic circuitry (e) D.C. amplifiers (f) test gear for field trials. Preference will be given to men with good academic qualifications. Applications should be sent to the Staff Manager (Ref. GBLC/549), G.E.C. Research Laboratories, Wembley, Middlesex. W 2513

ENGINEERS required for interesting work on the development of radio transformers and similar components. The work involves investigation of the application of new magnetic materials to transformer design. Applicants should write giving, full details of experience, etc., and salary required, to the Personnel Department (ED/50), E.M.I. Engineering Development Ltd., Hayes, Middx. W 2515

ENGINEERS required for Development, Servicing, and Instruction on Electronic equipment. National Certificate standard previous experience on Electronics or Radar desirable. Remuneration according to experience and qualifications. Apply—Local Employment Exchange, Ref. Construction Dept., The British Thomson-Houston, Co., Ltd., Rugby. W 2553

ENGLISH ELECTRIC Valve Co., Ltd., Chelmsford, have vacancies for young engineers to work on radio valve design and development. Applicants should be of Degree standard. Whilst experience of this type of work is desirable, it is not essential and otherwise suitable candidates will be considered. Write giving full details, quoting Ref. 497B to Central Personnel Services, English Electric Co., Ltd., 24/30 Gillingham Street, London, S.W.1. W 2485

CLASSIFIED ANNOUNCEMENTS
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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.

ESTIMATING ENGINEERS required by large progressive Engineering Company situated in the West Country. Applicants should have an extensive knowledge of the light Electro Mechanical industry. The vacancy is of a permanent and progressive nature. Pension scheme in operation. Applicants please write in confidence stating qualifications and salary required to Box No. W 2533.

ESTIMATOR required for their Electronics Division by Burndept Ltd., West Street, Erith. Knowledge of Electrical and Mechanical production; staff pension scheme. Applications stating age and experience to Personnel Manager. W 1438

EXPERIENCED Electronic Engineers required for interesting development work on a number of projects. Applicants should have a sound theoretical background with several years experience in the design and engineering of prototype electronic equipment. The posts are for permanent staff and offer good salaries and prospects. Please write giving full details and quoting ED/63, to Personnel Department, E.M.I. Engineering Development, Limited., Hayes, Middx. W 2516

EXPERIENCED ELECTRONIC Engineer required, to be responsible for the design of small power transformers, pulse transformers and similar components for a radar project. Opportunity to gain experience in other electronic branches of the project. Minimum qualifications are H.N.C. or Final C. and G. Certificate. Apply Employment Manager, Vickers-Armstrongs Ltd., (Aircraft Section), Weybridge, Surrey. W 2521

FERRANTI LTD., EDINBURGH—Require additional Staff for their Engineering Division engaged on Electro/mechanical instruments and radar equipment. Duties involve (a) the engineering and production design of new items to be put into production after the prototype has been evolved in the laboratories; and (b) the clearing of technical snags during the various stages of production. Applicants should be fully qualified Engineers and preferably have (a) Degree or Corporate Membership of one of the professional institutions; (b) several years' experience in production design of instrument or radar equipment; and (c) knowledge of production methods. Opportunity for initiative; good prospects; staff pension scheme. Apply quoting reference "E.D.," state salary expected and give full details of training and experience in chronological order to the Personnel Officer, Ferranti Ltd., Ferry Road, Edinburgh. W 2468

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

FERRANTI LTD. Moston Works, Manchester, have staff vacancies for circuit development work associated with a long-term telecontrol subject. Vacancies exist in the Senior Engineer, Engineer and Technical Assistant grades. Salaries: according to age and experience, for engineers and senior engineers, within the range £500 to £1,200 p.a., and for technical assistants between £400 and £600 p.a. Applicants should have a Degree in Physics or Engineering, Higher National Certificate, or its equivalent. 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 N.H.S. W 2545

FERRANTI LTD. have vacancies for Electronic Engineers in connexion with new developments in the Valve Dept. at Moston, Manchester. Applicants should have an Honours Degree in Physics or Electrical Engineering with vacuum physics or electronics as a subject. Experience in valve production techniques an advantage but not essential. Salary from £500 per annum according to qualifications and experience. Permanent staff appointments with superannuation. Forms of application from Mr. R. J. Hebbert, Staff Manager, Ferranti Ltd., Hollinwood, Lancs. Please quote Ref. Mil. W 2559

GLASS BLOWER. Benchwork and flame setting for pinchmaking and sealing in bulbs. Small scale experimental plant. High rate for experienced man. Slough area. Box No. W 1431.

GUIDED WEAPON PROJECTS at the Research and Armament Development Division of the Fairey Aviation Company, Limited, offer work of exceptional interest and opportunity to the following: Electronic Engineers experienced in micro-wave, pulse or communication techniques. There are both senior and junior vacancies and although a Degree or equivalent is normally required, applicants who lack such a qualification but who have considerable experience will also be considered. A Senior Electro-Mechanical Engineer for servo-mechanism analysis and automatic control design; electro mechanical, hydraulic or pneumatic. Accommodation assistance will be given in selected cases. Pension scheme. Good salaries. British born applicants wishing to be interviewed should send full details to the Manager, Dept. E., The Fairey Aviation Company Limited, Research & Armament Development Division, Heston Aerodrome, Hounslow, Middlesex. Engagements are subject to the Notification of Vacancies Order 1952. W 1426

H.F. HEATING ENGINEERS are required by the English Electric Company for their Industrial Electronics Department. These vacancies are for junior and senior Engineers with good experience of valve type H.F. Heaters. These are permanent and progressive appointments offering excellent opportunities for qualified engineers or those with sound practical experience of this class of work. Interviews can be arranged for Saturday mornings. Write, giving full details and quoting Ref. 357D to Central Personnel Services, English Electric Company, Limited, 24/30 Gillingham Street, London, S.W.1. W 2570

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

JUNIOR ELECTRONIC ENGINEER required by old established Company in Surrey. Apply by letter giving details of qualifications, experience and salary required to Box No. W 1446.

LABORATORY ASSISTANT required by loudspeaker manufacturers. Experience in a similar capacity, together with some knowledge of drawing office practice an advantage; the work is interesting and varied and the situation offers scope for initiative. Write giving full details of age, experience and salary required to Electro Acoustic Industries Ltd., Broad Lane, London, N.15. W 1434

LIAISON ENGINEER required in the Sales Department of large light Electrical Engineering Company situated in the London area. The selected applicant will be required to act as Liaison Engineer between Government Departments, Contractors and the company, and should have some experience of this type of work. The successful applicant will have technical qualifications and will be competent to conduct and discuss technical matters with Senior Officials of the various Government Departments. Applications should be made stating fullest details to Box No. W 2552.

McMICHAEL RADIO LTD., require qualified Draughtsman with experience in the Mechanical Design of Radio and Electronic Instruments for the Government Services. Salary will be commensurate with ability. Write stating age, training, experience and salary required to The Chief Engineer, Equipment Division, McMichael Radio Ltd., Slough, Bucks. W 2453

McMICHAEL RADIO LTD., require Senior Project Engineers in their Equipment Division Development 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. Salary will be commensurate with ability. Write stating age and full details of training, qualifications and experience to The Chief Engineer, Equipment Division, McMichael Radio Ltd., Slough, Bucks. W 2454

MULLARD RESEARCH Laboratory in Surrey has a number of vacancies suitable for Honours Graduates in Physics, Electrical Engineering, Mathematics or for persons with other but similar qualifications for work on: 1. Line Communications. 2. Radio Communications. 3. Radar. 4. Computors. 5. Electronic Measurement and Control Devices. 6. Metal Physics. 7. Electron Accelerators. 8. Television. 9. Ultrasonics. Previous experience in one or more of these fields is an advantage but is not essential and equal significance is attached to the candidate's potential ability to apply himself to such work. In addition to these posts there are a number for which several years' experience in addition to academic qualifications is essential: 1. Development of carrier systems and filter design. 2. Communication receiver and transmitter design. 3. Research and development associated with television reception. Rates of pay are proportional to qualifications, experience and age. Publication of original work wherever possible is desirable and is encouraged. Successful candidates are elegible for the superannuation scheme. Applications should be made in the first case to the Personnel Officer, Mullard Research Laboratory, Redhill, Surrey. W 2480

MURPHY RADIO Limited have a vacancy in the Electronics Division for a Technical Writer for publications dealing with Radio, Radar and similar equipment. Duties will consist of the preparation of Technical Handbooks and the editing of descriptive matter, etc. Write giving full details of experience and qualifications to Personnel Manager, Murphy Radio Ltd., Welwyn Garden City. W 2511

MURPHY RADIO require Engineers with knowledge of Magnetic Amplifiers and Servo-mechanisms. Applicants should have the mathematical and engineering knowledge necessary to design systems and undertake original development work in this field. Apply giving full details to Personnel Manager, Murphy Radio, Ltd., Welwyn Garden City. W 2479

MURPHY RADIO Ltd., offer the following vacancies in an expanding programme covering the field of domestic equipment and many branches of Electronic Development: (1) Senior Development Engineers having Degrees in Engineering or Physics with post graduate experience of equipment design who would be capable of leading a development team. (2) Development Engineers with similar academic qualifications having less or no industrial experience. (3) A Specialist Engineer with good academic qualifications having a sound knowledge of components and raw materials used in the Radio industry. This vacancy is only suitable for an applicant who is experienced in Electrical measurements and life testing of components. These posts are permanent and pensionable and offer good opportunities for advancement. Applications giving full details of experience and qualifications should be forwarded to the Personnel Manager, Murphy Radio, Ltd., Welwyn Garden City. W 2439

NATIONAL COAL BOARD.—Applications are invited for the appointment of a senior Electronic Engineer at the Central Research Establishment, Stoke Orchard, Near Cheltenham, to undertake the design and provision of electronic devices as required for research. Considerable responsible experience of this type of work and a wide knowledge of electronics circuit design (other than radio) are essential. The post is superannuable and appointment will be as Senior Scientific Technologist on the scale £670 x £25 to £820 per annum, initial salary depending on qualifications and experience. Apply in writing, giving full particulars (in chronological order) of age, education, qualifications and experience (with dates) to National Coal Board, Establishments (Personnel), Hobart House, Grosvenor Place, London, S.W.1, marking envelope TT/439. Original testimonials should not be forwarded. Closing date 12th April, 1952. W 2538

NELSON RESEARCH Laboratories, English Electric Company Limited, Stafford, have vacancies in their electric computing laboratory for graduates with a good Honours or Higher

CLASSIFIED ANNOUNCEMENTS
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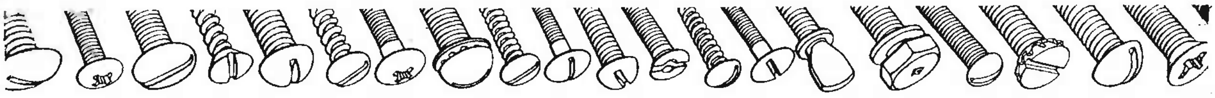
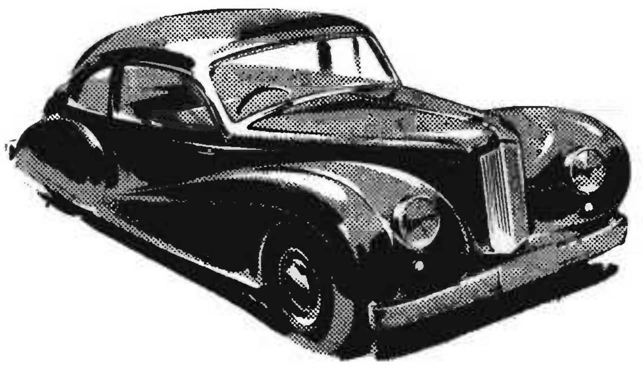
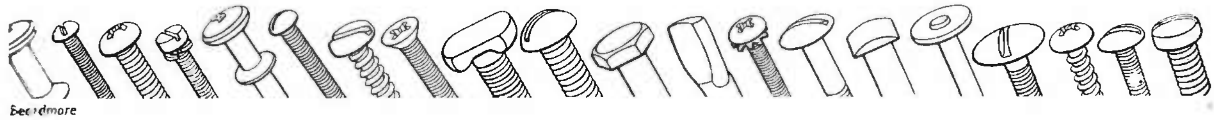






SITUATIONS VACANT (Cont'd.)

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.

Degree in Physics or Engineering interested in this field. Vacancies are available both for new graduates and for men with several years radar design or development experience or with some experience in computing projects. Write with full details mentioning Ref. 305D to Central Personnel Services, English Electric Co., Ltd., 24/30 Gillingham Street, London. S.W.1. W 2555

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

NORTHERN POLYTECHNIC, London, N.7. The Governing Body invite immediate applications for appointment as full time Lecturer in Telecommunications Engineering for the three year full time course in preparation for the full technological certificate of the City and Guilds of London Institute in Telecommunications Engineering. A knowledge of radar and television engineering is desirable. Salary scale —£900 x £25 - £1,000, plus London allowance. Form of application, together with full particulars, will be forwarded on receipt of a stamped, addressed foolscap envelope. W 2540

PHYSICISTS or Engineers are required for work concerned with the development and application of semi-conductor devices. This expanding field offers good opportunity for advancement. Preference will be given to men with good qualifications and with some experience in this or an allied field. Apply to the Staff Manager (Ref. GBLC/O/569), Research Laboratories of The General Electric Co., Ltd., Wembley, Middlesex, stating age and record. W 2519

PHYSICISTS and Electrical Engineers. Interesting and varied work is available in a West London Research Department, for versatile qualified Physicists and Electrical Engineers on applied measurements—electrical, acoustic and mechanical. Persons should have several years industrial experience of this type of work. Write to us for a preliminary interview and also state full details of education, qualifications, experience, and salary required. Suitable persons will be required under the Notification of Vacancies Order, 1952, to make their application through the Ministry of Labour or a Scheduled Employment Agency. Write to Box A.E. 780, Central News Ltd., 17 Moorgate, London, E.C.2. W 2534

RADAR ENGINEER preferably with experience of R.C.M. on centimetre wavelengths, required for laboratory within 30 miles of London. Progressive post. Starting salary £600-£1,000 per annum according to experience. House available to married man. Reply quoting reference DEF to Box No. W 2548.

RADIO MECHANIC required. Apply The Ever Ready Co. (G.B.), Ltd., Hercules Place, Holloway, N.7. W 2562

RADIO/RADAR Foreman required on the assembly of electronic instruments. Only men with experience of quality production in small batches need apply. Minimum starting salary £600 p.a. Salaried position—bonus, etc. Box No. W 1427.

SALES ENGINEER, with first rate technical qualifications required to take charge of electronic and special products section of expanding Sales Department of established Company, London, having varied interests in this field, U.S.A. connexions and progressive manufacturing policy. Must have initiative and proved sales organising ability with experience in supervision of estimating and control of technical sales correspondence. Write giving full details of age, education, technical qualifications, experience and salary required. Box No. W 2571.

SENIOR DESIGN Draughtsman required by manufacturers of electrical and electronic equipment. A thorough knowledge of materials and production methods is essential. The salary will be commensurate with qualifications and experience. Box No. 2471.

SERVICE ENGINEER required having good knowledge of reciprocating aircraft engines and reasonable knowledge of electronic practice. Preference will be given to applicants with experience of electronic engine performance analysis. Successful applicant will be required to travel in U.K. and Continent. Salary commensurate with qualifications and experience, but not less than £450 p.a. Superannuation scheme. Apply with full details of age, experience and salary required to the Personnel Manager, Sperry Gyroscope Co., Ltd., Great West Road, Brentford, Middlesex. W 2489

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

SUPERVISOR to lay out and control assembly of light electrical equipment required. First class man fully experienced in wiring up of compact precision electrical equipment, able to work from schematic and assembly drawings, and to break jobs down for belt or line assembly. Housing can be arranged. Substantial prospects. Write in confidence giving full particulars to Box No. W 2525.

TELEPHONE Transmission Engineer, experienced in carrier equipment, filter design, and testing required by American manufacturers for work in Italy. Box W 1437.

TELEVISION ENGINEER required, experience in fault diagnosis, capable of using modern test equipment—circuit alignment by visual methods, etc. Salary £400-£500 p.a.—situation, Reading. Apply Box 779, Granthams Advertising, Reading. W 1435

THE BRITISH Iron and Steel Research Association. Technical Assistant required by the above Association for work in the Instruments Section of their Physics Laboratory in Battersea. Duties will be concerned with the design and development of industrial measuring and control instruments. A National or Higher National Certificate in Electrical Engineering or applied physics. Age range 20-25. Starting salary up to £480 per annum according to age, qualifications and experience. Written applications only, quoting "Electronics" to Personnel Officer, B.I.S.R.A., 11 Park Lane, London, W.1. W 2539

THE BRITISH SOCIETY for Research in Agricultural Engineering invites applications for appointment at the National Institute of Agricultural Engineering in the following Depart-

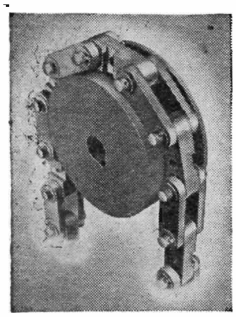
CLASSIFIED ANNOUNCEMENTS
continued on page 10

THE DE HAVILLAND ENTERPRISE has vacancies at Hatfield, Herts., for Draughtsmen of all grades for work of high National importance. Posts are permanent and progressive for able and energetic men in mechanical, hydraulic, electrical and electronic fields. Senior designers and juniors anxious for interesting and entirely new work are needed at once. Write in confidence, giving particulars of education and experience, stating whether British born. Interview expenses refunded. Apply to the local Employment Exchange or scheduled agency. W 2543

Artillery...

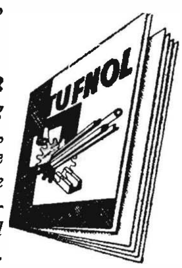
FOR BRIGHT SPARKS

Positively ' bang-on ', this use of Tufnol to form the handle and guard of an electrode holder — although high electrical insulating properties are by no means the only shots in the locker of this very versatile material. Its uses are legion arising out of its sympathetic working with metals in the form of bearings, pulleys, and gears — its resistance to moisture and corrosion — its low specific gravity combined with good structural strength. For the most part, Tufnol is simply bought in the standard forms of sheets, tubes, rods, bars, angles, channels, and other sections, to be machined as one would metal or hardwood. But it can also be supplied in specially moulded shapes or as finished machined components. Even those who have used Tufnol from the beginning, still find its possibilities endless.



Tufnol chain and jockey pulley for use in a de-scaling plant where they work in a boiling acidulated solution. The chain withstands a pull of 480 lbs.

CAN TUFNOL HELP YOU?
Informative literature is available giving full information on Tufnol. Furthermore, our enthusiastic Technical Staff welcome any new problems involving the possible use of this versatile material. An indication of your requirements in a letter, will bring a prompt and helpful reply.



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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.

ments: Grain (G.1) Experimental Officers or Assistant Experimental Officers for work on (a) Combustion and heat transfer problems and capable of carrying out research and development to prototype stage. Two or three years industrial and/or research experience: (b) electrical instrument design and electronics control and supervisory equipment, with at least four years experience in industry and/or research. Intermediate B.Sc., Higher National Certificate or their equivalent essential. Salary scale: £264-£755 according to age and experience. Horticultural Engineering (H.2) Scientific Officers for work on (a) glasshouse heating, involving knowledge of electronics or microclimatology, (b) work on fundamental aspects of machinery for plant pest and disease control. Candidates must hold first or second class Honours Degree in Engineering or Physics and research experience is desirable. Salary scale: £418-£676 according to age and experience. This Department has vacancies also for Assistant Experimental Officers (H.3) who should hold Intermediate B.Sc., Higher National Certificate or their equivalent and possess a knowledge of electronic engineering or physics. Salary scale: £264-£555 according to age and experience. Mechanical Engineering (M.4) Scientific Officer for research and development work on mechanical engineering problems, including the development of laboratory and field equipment for agricultural and agricultural engineering research. First or second class Honours Degree in Mechanical Engineering essential and industrial and/or research experience desirable. Salary scale: £418-£676 according to age and experience. Application forms obtainable from Secretary, N.I.A.E., Wrest Park, Silsoe, Beds., on receipt of stamped addressed foolscap envelope. Completed applications, quoting reference numbers, to be submitted within 14 days of the appearance of this advertisement. Box No. W 2512.

THE GENERAL ELECTRIC CO., LTD., Browns Lane, Coventry, have vacancies for Development Engineers, Senior Development Engineers, Mechanical and Electronic, for their Development Laboratories on work of National Importance. Fields include Microwave and Pulse Applications. Salary range £400-£1,250 per annum. Vacancies also exist for Specialist Engineers in component design, valve applications, electro-mechanical devices and small mechanisms. The Company's Laboratories provide excellent working conditions with Social and Welfare facilities. Superannuation Scheme. Assistance with housing in special cases. Apply by letter stating age and experience to The Personnel Manager (Ref. CHC). W 2491

UNIVERSITY STUDENTS of Physics, Electrical and Mechanical Engineering who graduate this summer, are invited to send details of their records to the Staff Manager (Ref. GBLC/604) Research Laboratories of The General Electric Co., Ltd., North Wembley, Middlesex. Attractive openings on experimental work will be available for such men together with a few for graduates with research experience. W 2567

VACUUM TUBES for Television Transmission. Due largely to the rapid expansion of the export business of the Pye Group in this field and the increasing demands of defence work, the vacuum tube company of the Group, Cathodeon Ltd., requires, for work on a wide range of projects, such as camera tubes, photocells, cathode ray tubes, valves, etc., a number of experienced people of all grades, including the following: Vacuum Engineer/Physicist for work on tube development and investigations. Test Equipment Engineer with knowledge of television techniques for the design and construction of test gear for use in such work. Operators of all types, experienced in this type of work, including glassblowers, pumpers, assemblers, etc. Write, in confidence, giving details of experience, salary required, etc., to Cathodeon Ltd., Church Street, Cambridge. W 1440

WAYNE KERR require several senior and junior draughtsmen for design and development work on high priority electronic test equipment. The work is interesting and offers considerable scope for men with initiative and design ability. Attractive salaries in excess of the revised A.E.S.D. rates will be offered to suitable applicants. Write giving details of past experience to Wayne Kerr Laboratories Ltd., Sycamore Grove, New Malden, Surrey. W 2504

SITUATIONS WANTED

AMBITIOUS electronic engineer (36) with wide executive experience in small businesses, ideas, and a capacity for hard work, wishes to join manufacturer where these qualifications would be of value. Might suit owner-manager wishing to be relieved of some responsibility. London area preferred, but all propositions considered. Box No. W 1430.

HONOURS ENGINEERING graduate with considerable Electronic experience will undertake Technical Design, Investigation or Journalism on free-lance basis. Location London. Box No. W 1424.

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

FOR SALE

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

ELECTRONIC HEATER or Brazing Machine, by Electric Furnace Co., type T.10/4MW., Power input 15 KVA, Average Operating Frequency 500 k.c., Maximum output current 140 amps Radio frequency, suitable 380/440 Volts. 50 cycles, 3 phase, Spare Oscillator Valve, original cost £1,400 will accept offer. A. and B. Utilities, 42 St. Mary's Street, Southampton. W 1442

MESSRS. HOPTON RADIO wish to thank past and present customers for their patronage and to announce that their business has been acquired by Servotronic Sales to whom all enquiries for Magslips, Selsyns and Servo-control equipment should be addressed. Servotronic Sales, 1 Hopton Parade, Streatham High Road, Streatham, London, S.W.16. Telephone: Streatham 6165. Erith 2479. Illustrated brochure and price list available to bona-fide applicants. Box No. W 2565.

FOR DISPOSAL. Approx. 800 lbs. M.E.A. No. 8 Laminations 0.004 thick Radio Metal. Box No. 1410.

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

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

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

OFFER required for Plessey Standard No. 2 Wavemeter. Condition as new. Box No. W 1436.

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

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

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

SERVICE

FIRM specializing in prototype developments of printed and potted circuits, invites inquiries from firms with Miniturization problems. Capacity also available for small scale production. Electro Technical Developments, 62 High Street, Croydon, Surrey. Croydon 1010. W 1445

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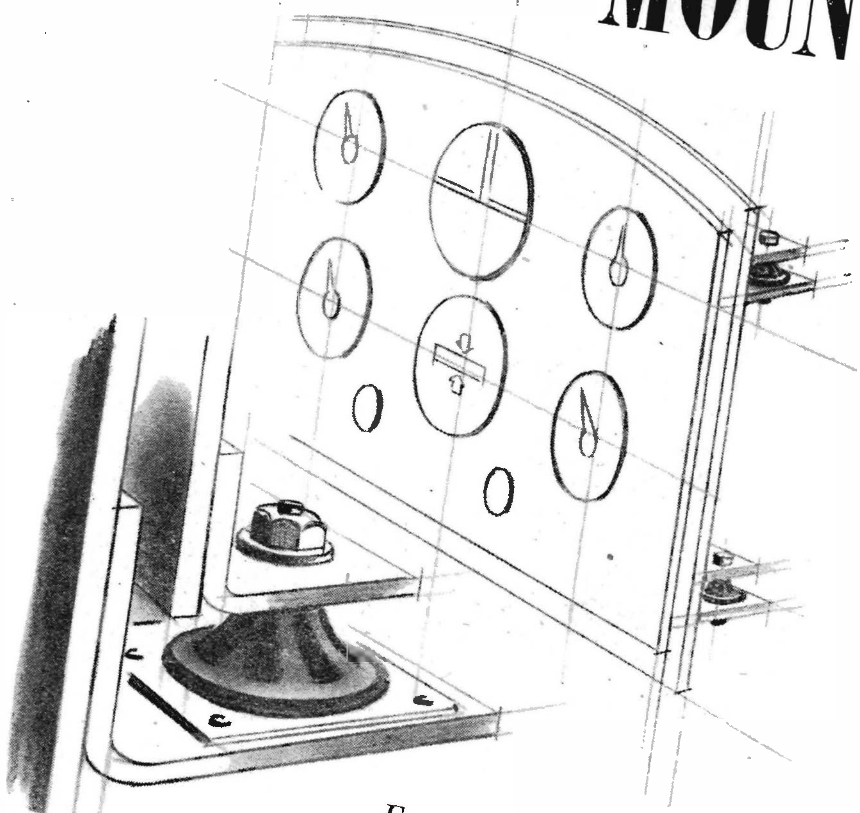

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Self inductance of primary winding at 300 c/s—1 volt drop	3.0 Henries	6.5 Henries
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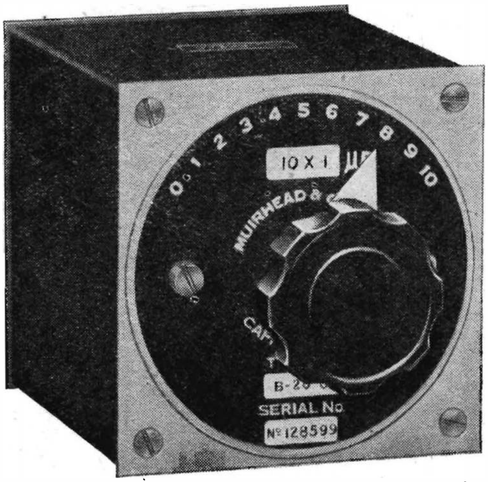

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Stability:	Within ±0.1%.
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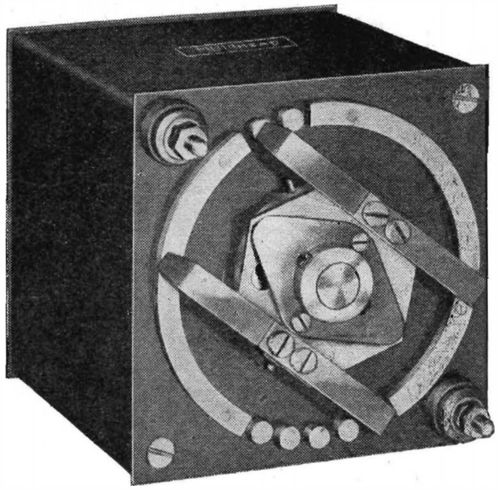

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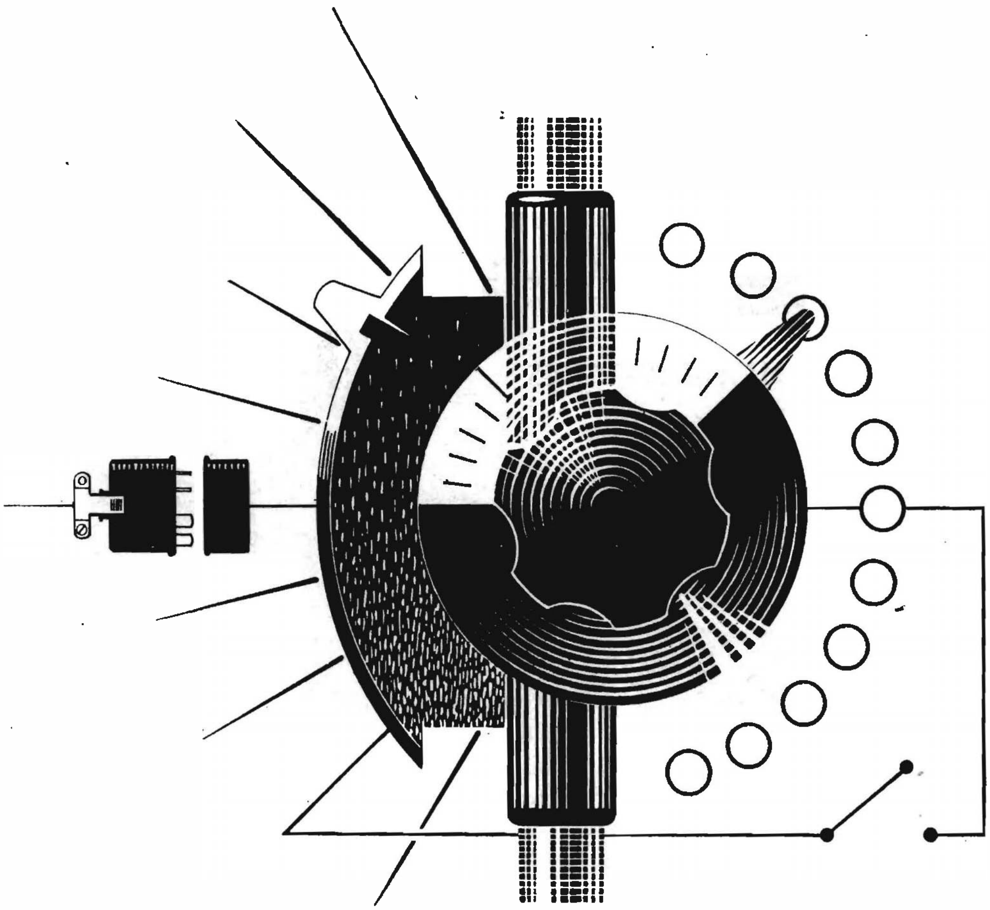

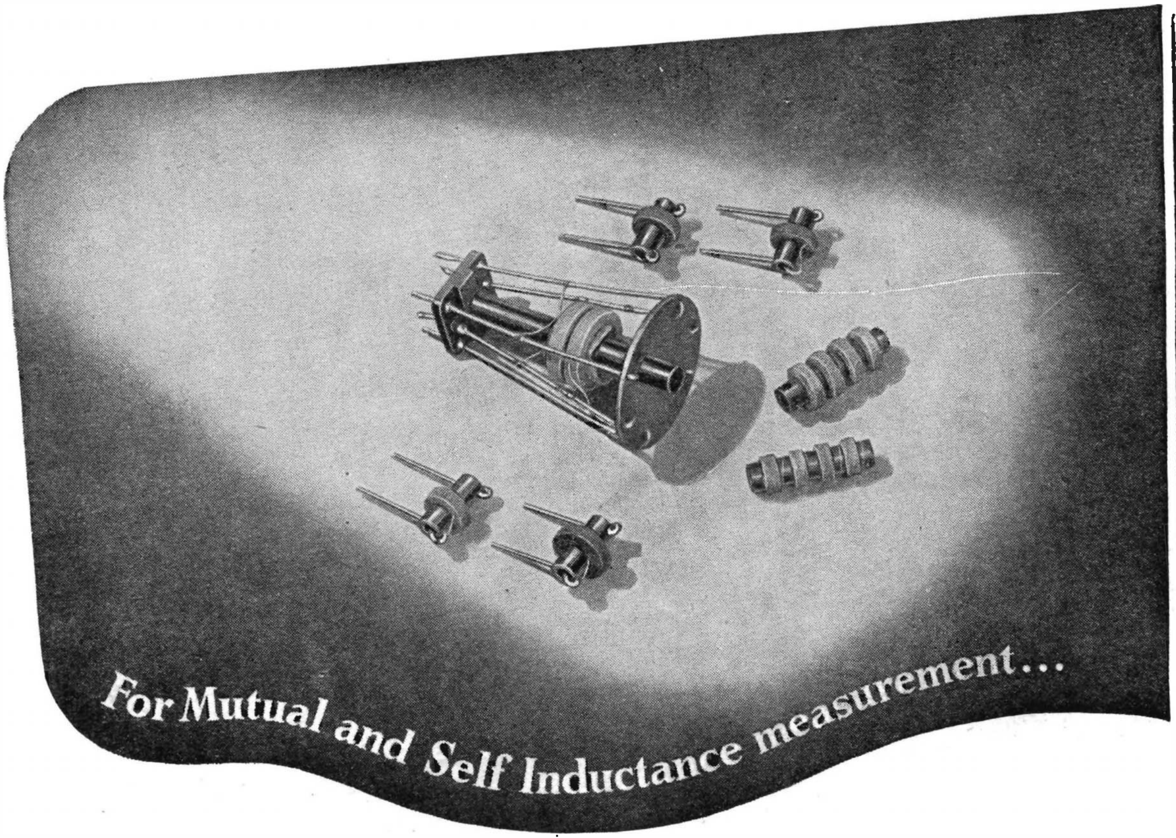

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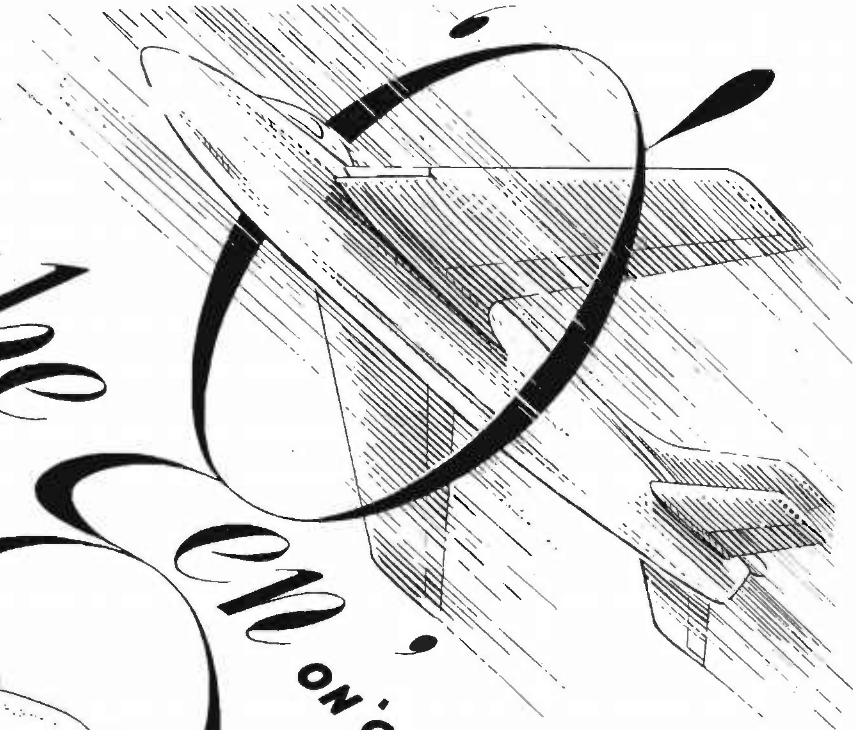

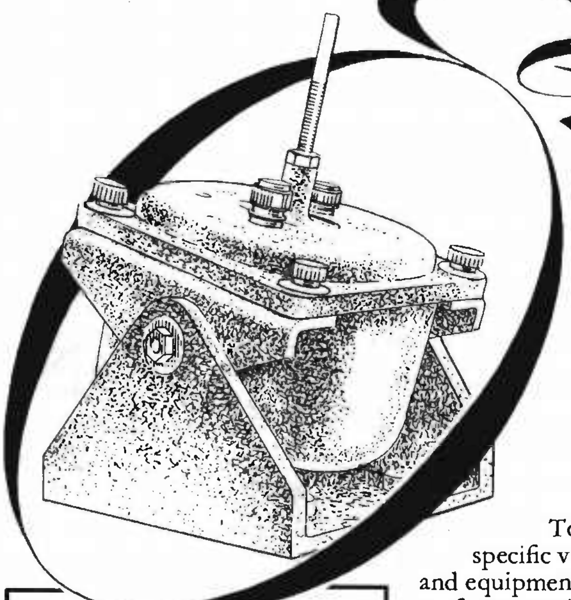

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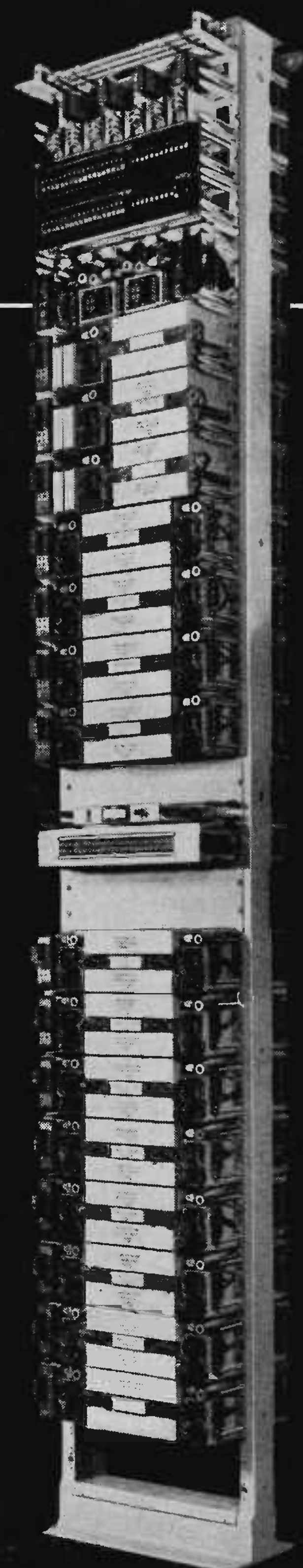

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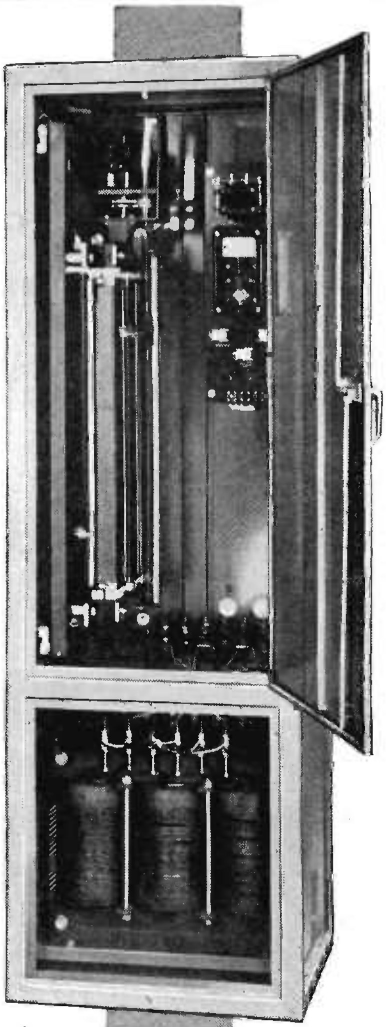

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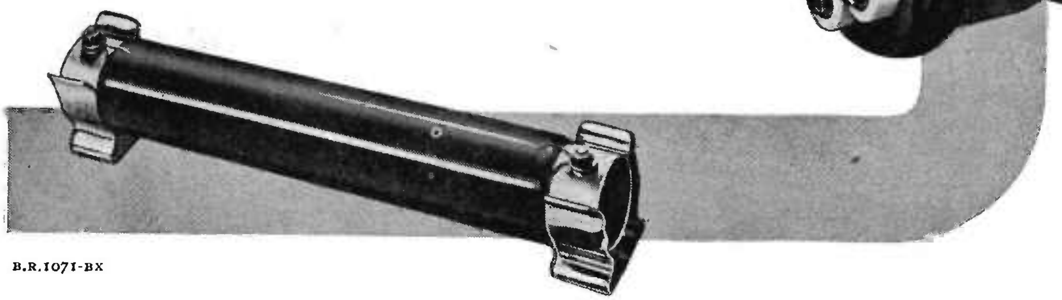

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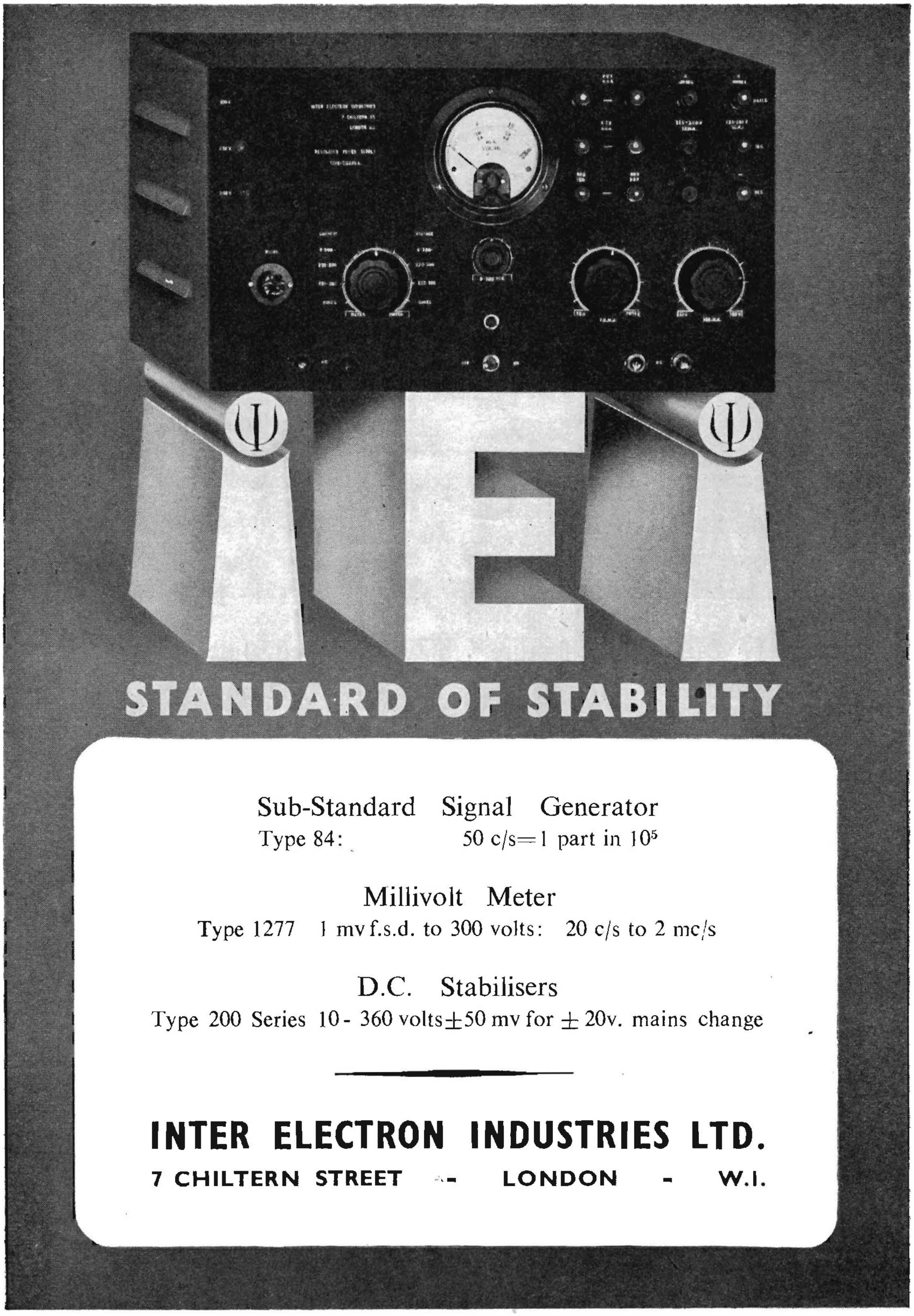

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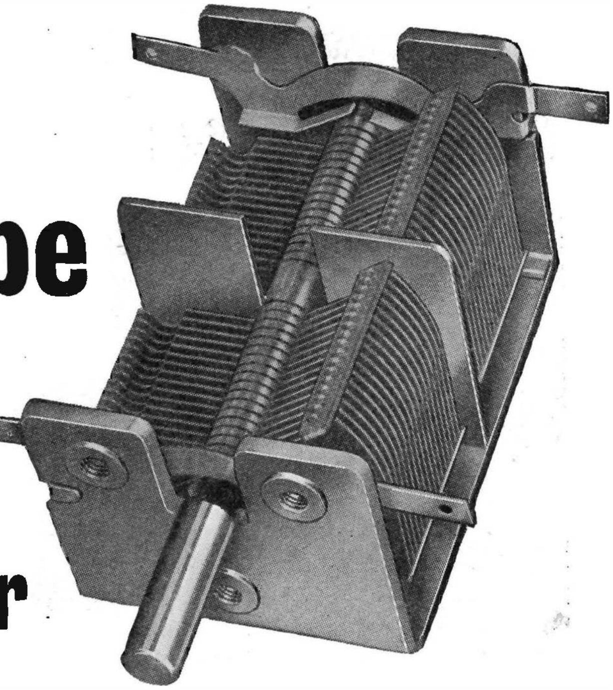
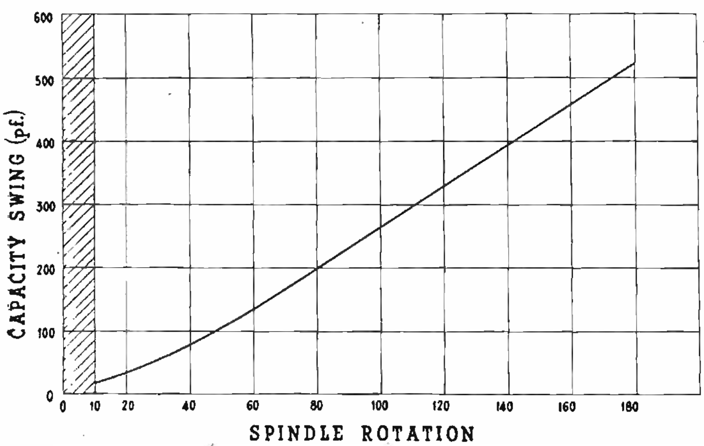
The NEW 'S' type MINIATURE variable condenser





Welcome news for radio designers and manufacturers: in the 'S' type variable condenser, Plessey has produced a new miniature component with electrical and mechanical efficiency of the highest order. Study these features:

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New form of bearing, reducing crackle.

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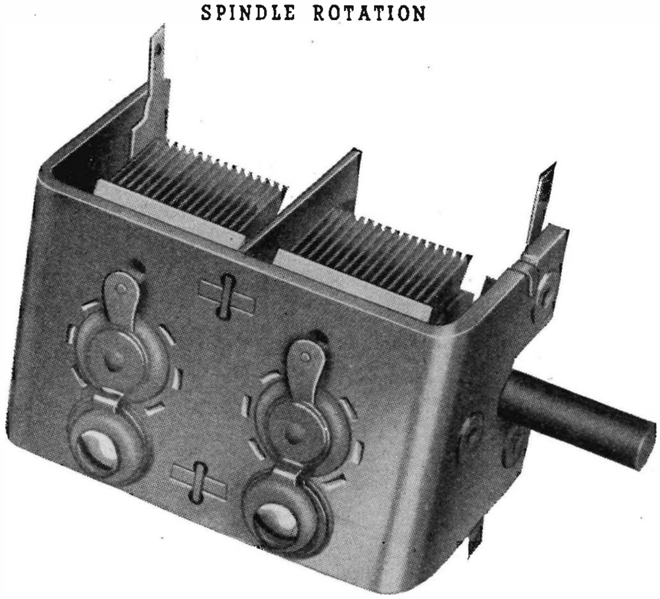

Plessey

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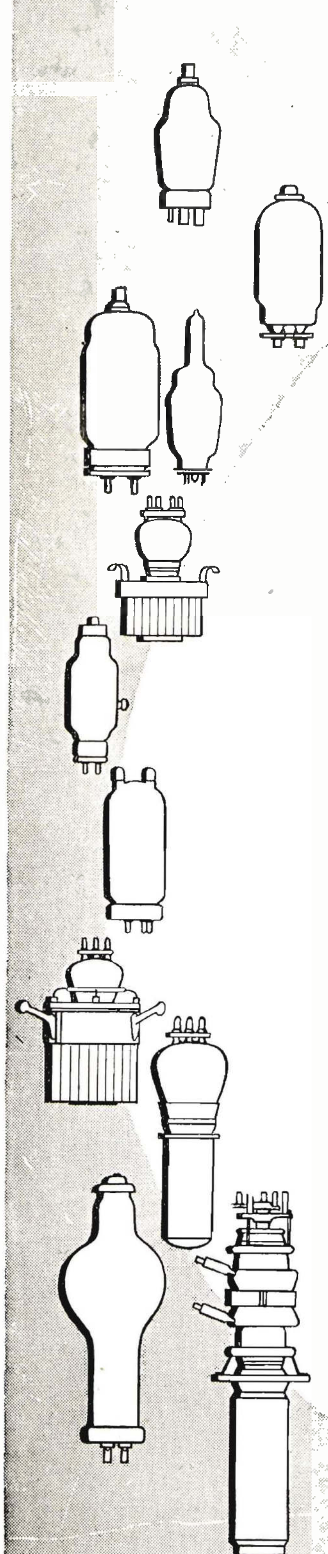

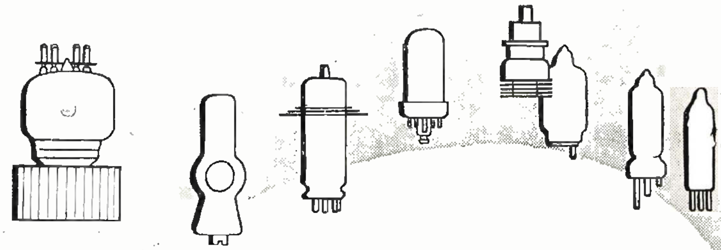

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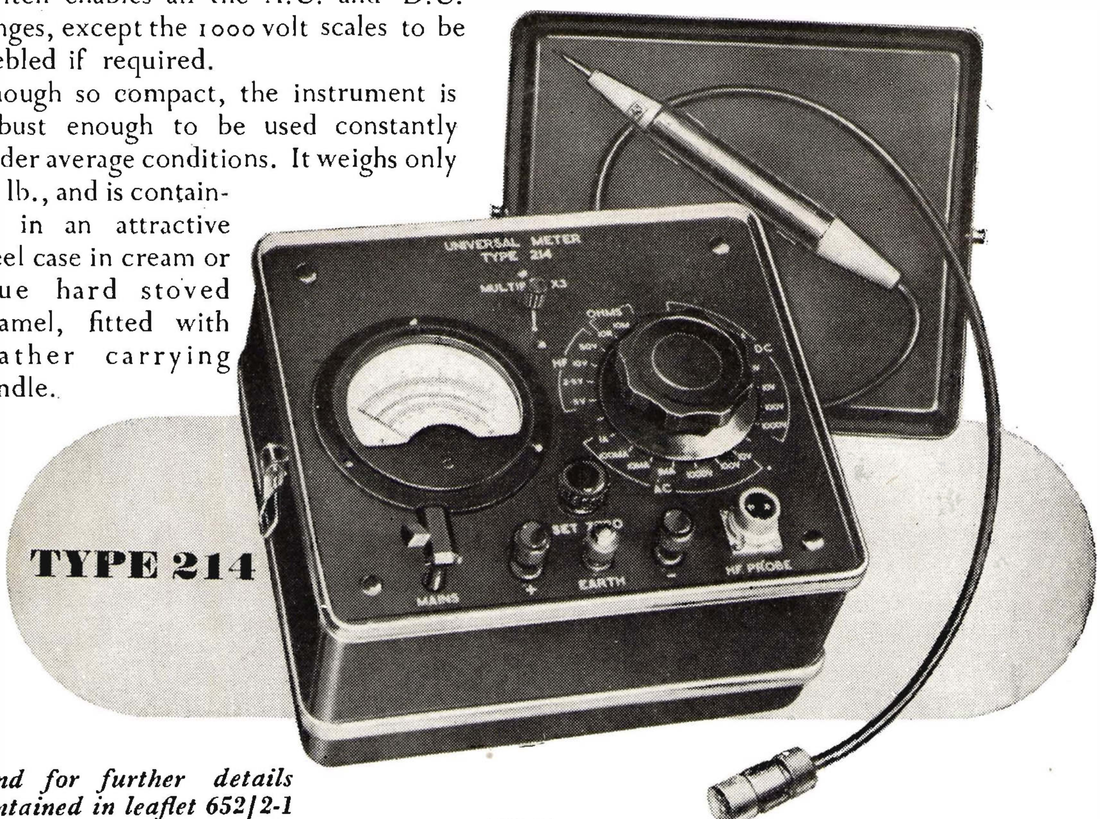

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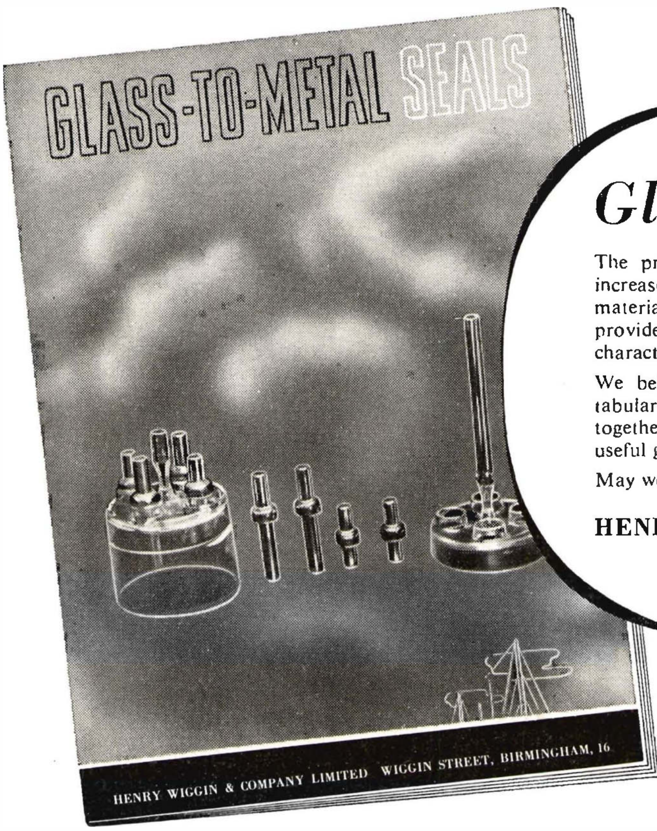

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We believe that our revised publication, which includes tabular data on the properties of the various grades of alloy, together with examples of their industrial use, will prove a useful guide to the selection of the correct grade of material.

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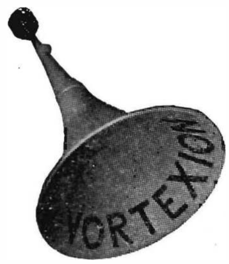

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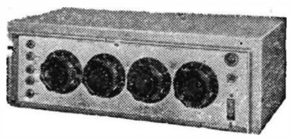

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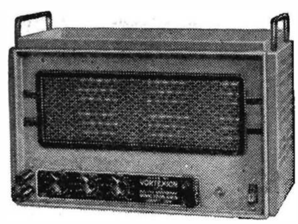
This unit has 4 built-in balanced and screened microphone transformers, normally of 5-30 ohms impedance. It has 5 valves and selenium rectifier supplied by its own built-in screened power pack, consumption 20 watts. Suitable for recording and dubbing, or large P.A. installations since it will drive up to six of our 50 watts amplifiers whose base dimensions it matches. The standard model has an output impedance of 20,000 ohms or less, any impedance can be supplied to order.



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These are fitted in well-ventilated steel cases with recessed controls as illustrated.

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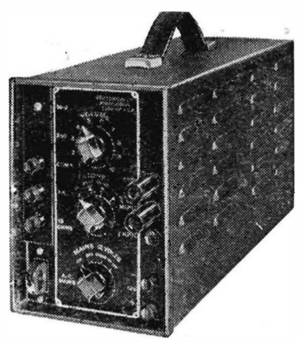
as illustrated for single or double P.E.C. input with separate adjustable bias. Full range of tone controls to suit all needs with built-in Exciter Supply if required.



TYPE C.P. 20A AMPLIFIER for A.C. Mains and 12 volt working giving 15 watts output, has switch change-over from AC to DC and " Stand-by " positions. Consumes only $5\frac{1}{2}$ amperes from 12 volt battery. Fitted with mu-metal shielded microphone transformer for 15 ohm microphone, provision for crystal or moving iron pick-up with tone control for bass and top. Outputs for 7.5 and 15 ohms. Complete in steel case with valves.

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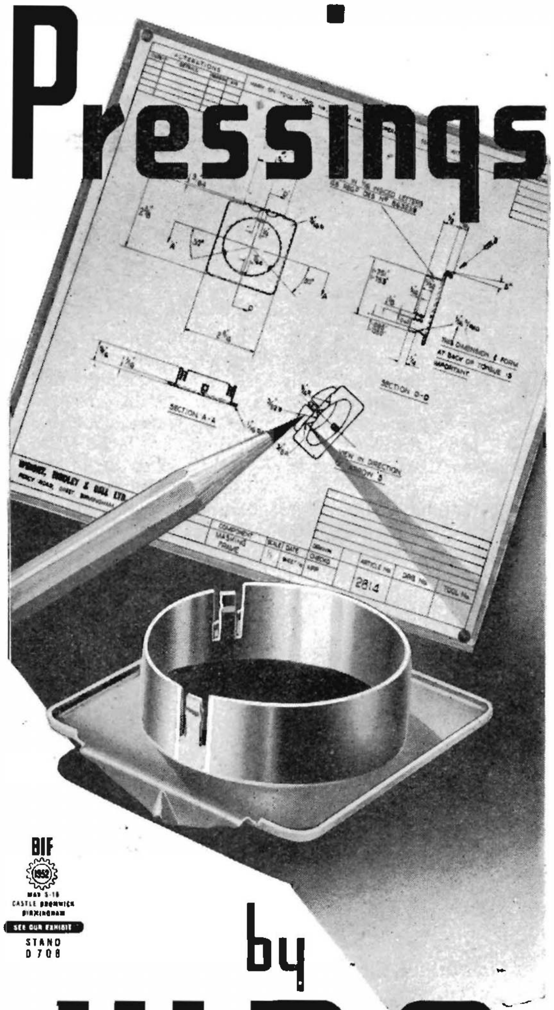

Electronic Engineering

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

Vol. XXIV APRIL 1952 No. 290

Contents

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

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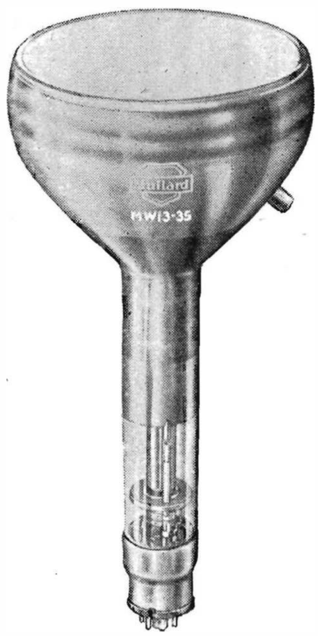

Cathode Ray Tubes for Television Studio Applications

DESCRIPTION	MW13-35	MW22-22
HEATER V_h I_h	6.3 V 0.3 A	6.3 V 0.3 A
LIMITING VALUES V_{a2} max. V_{a2} min. V_{a1} max. V_{a1} min. $-V_g$ max.	absolute ratings 11 KV 5.5 KV 450 V 200 V 200 V	design centre ratings 11 KV 7 KV 400 V 200 V 150 V
DIMENSIONS Max. bulb diameter Max. overall length Useful screen diameter	 127.5 mm 289 mm 108 mm	 230 mm 377 mm 214 mm
BASE	Octal	B12A

The Mullard cathode ray tubes, MW22-22 and MW13-35, have been specially designed to give high-grade pictures under the brilliant lighting conditions encountered in television studio work. They are both characterised by their exceptionally high definition and high brilliance. Halation has been reduced to an absolute minimum.

The MW22-22, which is a metallized tube with a nine-inch, white screen, is now being used extensively in television studio monitoring.

The MW13-35, being a compact tube, is finding wide application in television-camera viewfinding equipments. This tube is also metallized and has a white, flat-faced screen, five inches in diameter.

In addition to these two tubes, Mullard also have available a large selection of cathode ray tubes for use in television transmission quality monitoring systems, navigational radar equipments, and measuring and testing instruments. Full details of any of these tubes will be supplied on request.

Mullard

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Electronic Engineering

Vol. XXIV. **APRIL 1952** No. 290.

Commentary

FROM April 28 to May 3 the Institution of Electrical Engineers will be holding the third of its post-war Conventions and, unlike its predecessors it will not be confined to members of the Institution and their guests. This Convention on the British Contribution to Television will be opened by the Lord President of the Council, the Right Honourable Lord Woolton, C.H., and Addresses will be delivered by Sir John Hacking, President of the Institution and Sir Noel Ashbridge, Director of Technical Services, B.B.C.

In authorizing the Committee of the Radio Section to hold this Convention the Council of the Institution had decided that:

"The time is ripe to take stock of the position reached by television as a significant national service and the engineering and scientific factors lying at the root of its development."

The Council also considered it desirable:

"To place on record the pioneer work undertaken in Great Britain, not only in providing the first public television service in the world, but also in being responsible for many detailed technical applications since that time."

Advance copies of the papers are not available for inspection before we go to press, but we are impressed by the comprehensive list of survey and supporting papers and we applaud the Institution's decision to hold a Convention of this nature—the first of its kind it is believed—at a time when a number of countries overseas are engaged in the preliminary investigations which must precede the introduction of a television service.

In all, there will be some 80 survey and supporting papers, each written with authority and intended for discussion by the expert. As such therefore these papers are not likely to appeal to the layman, but their implications will be of interest to everybody and the developments they forecast are likely to have a profound influence on our way of life, both from the social and industrial point of view.

* * *

One of the more favourable legacies of the war was the benefit deriving from the many war-time inventions such as radar, and it was not surprising therefore that towards the end of the war an interdepartmental committee was set up to pilot these inventions into industry with the minimum of delay.

A National Research Trust Committee was called into being and as the result of their recommendations the Development of Inventions Act was passed in 1948 and the National Research Development Corporation was instituted whose terms of reference in broad outline were "to exploit and develope commercially discoveries and inventions made in laboratories operated by Civil and Defence Ministries, the Department of Scientific and Industrial Research or those sponsored by the Agricultural and Medical Research Councils, the Development Commission and, of course, the Universities."

To this end Parliament provided the Corporation with borrowing powers up to £5 million which, it was estimated, would be spent over the first five years of the N.R.D.C.'s existence.

The second annual report for the year ending June 30, 1951, shows how far the Corporation has progressed and in support of the N.R.D.C.'s statement, its Managing Director, the Earl of Halsbury, recently reviewed its activities in a paper before the Royal Society of Arts. He stated that during the first two and a half years of its existence it had handled some 2,500 cases of what he termed subject matter. Of these, about 1,000 had been sent in by members of the public who had sought the help of the corporation, but only two or three seemed to justify assistance. The remaining 1,500 came from the various government research laboratories, universities and industrial research organizations.

Of greatest immediate concern to us is the work which the N.R.D.C. is carrying out for the commercial exploitation of Electronic Digital Computors. As is well known, there are several computors already working in research laboratories in this country, but it seems that the greatest possibilities lie in the development of computors with more limited facilities for the routine requirements of commerce and industry, and we shall watch with interest this aspect of the N.R.D.C.'s programme.

* * *

We are sure that the following extract from *The Guilds' Engineer*—the official journal of the City and Guilds College Engineering and Radio Societies—deserves a wider notice. It is printed without alteration except for the italics.

"Some time ago, in the course of a law case dealing with a radio invention, it was necessary to explain to the judge the principles of magnetic induction. He was told, in terms that seemed clear and logical, about magnets, poles, field strengths and lines of force. Everyone thought he had followed all that had been said, and were extremely chagrined to hear him say that in order to get the matter clear in his mind, he would like to know *what happened in the spaces between the lines.*"

Distributed Amplification

By A. Cormack,* B.Sc.

The basic principle of the Distributed Amplifier is briefly outlined. Design details are given of two amplifiers having flat frequency response curves extending from L.F. *to* 170*Mc/s. One, a single stage amplifier, has a gain of* 18*db, the other a two-stage amplifier, produces a gain of* 28*db. A final stage giving an output impedance of* 75 *ohms is also discussed.*

THE Distributed Amplifier has had a rather curious history. The idea was conceived by W. S. Percival in 1936 (British Patent Specification No. 460,562, applied for July 24, 1936). Between then and 1948 little seems to have been published. Since 1948 several papers have been published and amplifiers are now available commercially in America.

The theory of operation has been explained very thoroughly elsewhere.[1] The name Travelling Wave Chain Amplifiers is sometimes applied to these amplifiers, but to avoid risk of confusion with the Travelling Wave Tube, also for the sake of simplicity, the name "Distributed Amplifier" has been adopted. The purpose of this paper is to show how such an amplifier may be designed and to give practical details of amplifiers employing the easily

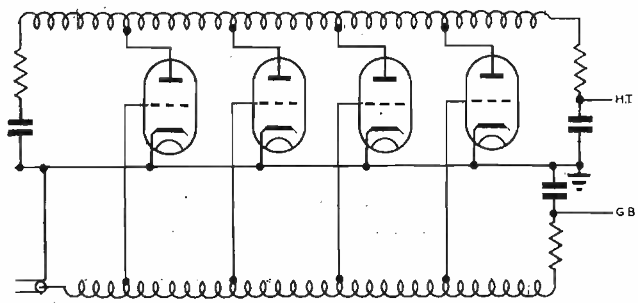


Fig. 1. A single stage of four sections

obtainable high slope pentode Z77. For readers not already acquainted with the principles of distributed amplification a brief description is included. The amplifiers described were developed for use with a very wide range swept oscillator,[2] and although the frequency response curve before trimming is reasonably flat the instrument was found most valuable for final adjustments.

Basic Principles

It has been shown that for any given valve type, no matter how complex the coupling between stages, there is a maximum "bandwidth-gain product." Hansen[3] shows that a maximum bandwidth-gain product of

$$2{\cdot}53\, g_m/\pi C$$

is obtained by using a four terminal band-pass coupled stage. (g_m = mutual conductance of valve, C = sum of input and output capacitances). By connecting valves in parallel the increase in g_m is offset by the corresponding increase in input and output capacitances. In the distributed amplifier valves are connected in parallel in such a manner that their mutual conductances effectively add, while the input and output capacitances remain separate. The capacitances of a single valve determine the characteristics of the complete amplifier.

A number of valves have their grids connected at equal intervals along an artificial transmission line and their

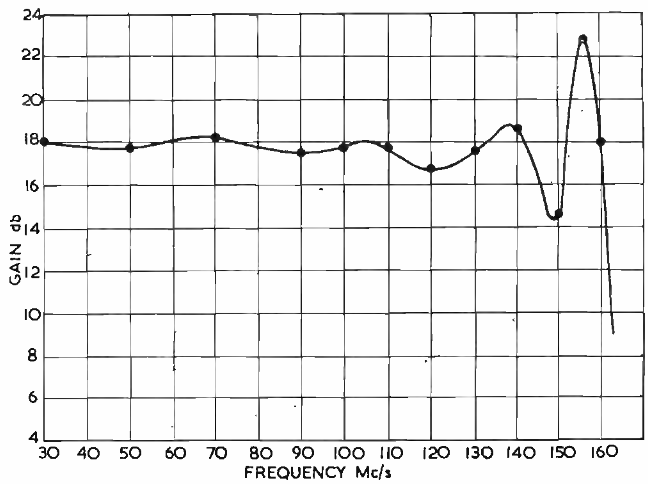


Fig. 2. Response curve of a six section single stage

anodes in a like manner along another transmission line. The input and output capacitances of the valves provide, at least in part, the shunt elements of the transmission lines. The lines are constructed so that the velocity of propagation along each is the same, and they are correctly terminated at both ends.

A circuit diagram of one stage, consisting in this case of four sections, is shown in Fig. 1. As in a recent paper on this subject[1] each valve together with its sections of transmission line will be called a section; when n sections are connected completing the transmission line this forms one stage. When such stages are connected in cascade in the conventional manner they are called cascaded stages.

A signal is fed into the left-hand end of the grid line, causing a wave to travel down the line. When this reaches the grid of the first valve a change in anode current occurs causing a similar signal to travel along the anode line in both directions. Similarly with all the other valves. All signals travelling to the left and right will be absorbed in their respective termination. Since the two lines have the same velocity of propagation,

*Research Laboratories of The General Electric Co., Ltd.

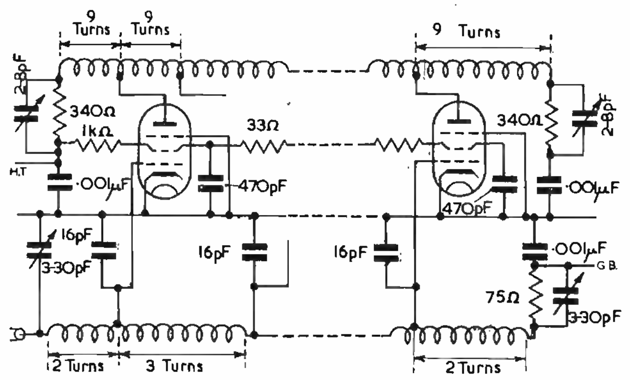


Fig. 3. The line terminations

the time taken for a signal to travel from the input end of the grid line to the right-hand (output) end of the anode line will be the same no matter by what path it travels. Thus, all the signals arriving at the output end of the anode line will be in phase and will add.

Let us assume that the transmission lines are loss free.

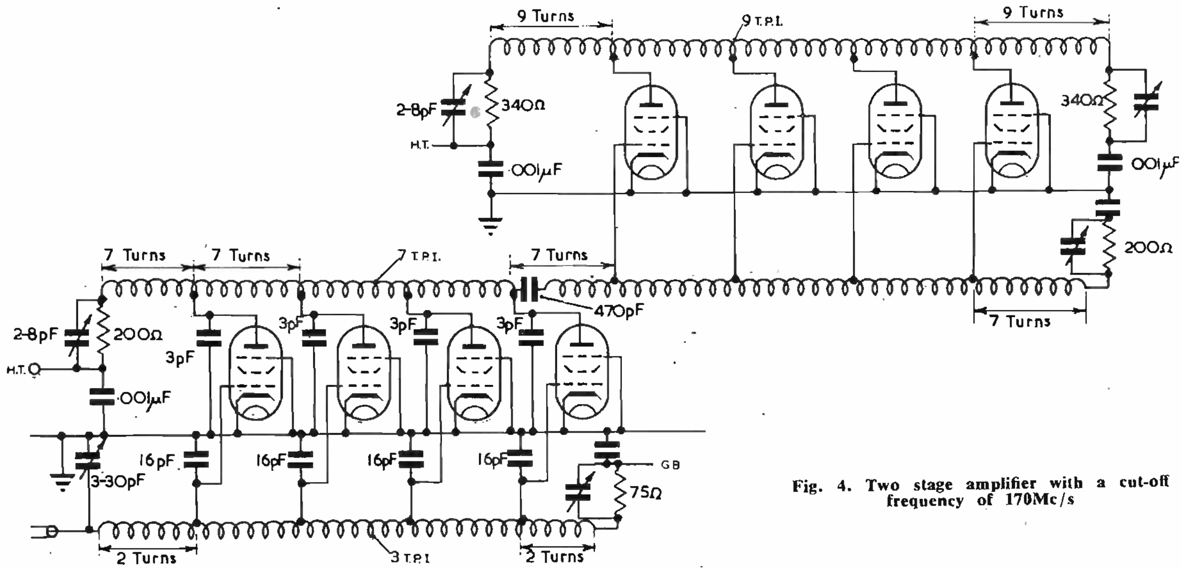


Fig. 4. Two stage amplifier with a cut-off frequency of 170Mc/s

Consider an instantaneous voltage e_g applied to the grid line. This will cause an instantaneous current $i_a = g_m e_g$ to flow in each valve.

Each valve will cause a current $i_a/2$ to flow to the right, therefore

$$\text{Output voltage} = n \times i_a/2 \times Z_o = \frac{n\, e_g g_m Z_o}{2}$$

therefore

$$\text{Voltage gain} = \frac{n\, g_m Z_o}{2}$$

Where n = number of sections

g_m = mutual conductance

Z_o = characteristic impedance of line

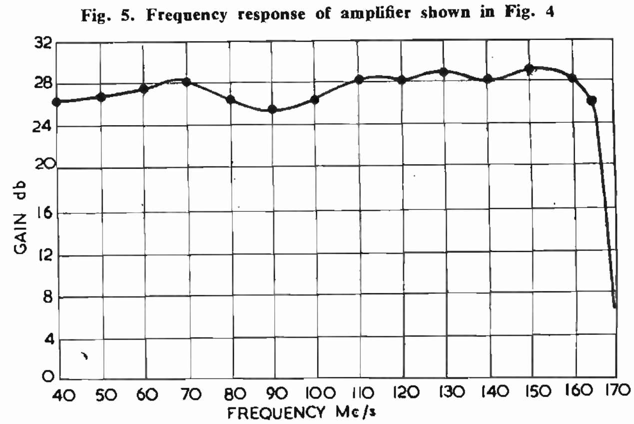
Thus, provided the transmission lines are loss free the gain can be increased simply by adding more valves. Stages may be cascaded by connecting the output end of an anode line of one stage to the input end of the grid line of another. If the impedance of the two lines is different then an impedance matching device will have to be connected between the two. It can be shown[1] that to obtain any given gain using the least number of valves, stages having a voltage gain of 2·718 times should be used. It will be appreciated that as Z_o is practically independent of frequency at frequencies well below cut-off, the gain can be maintained right down to D.C.

Choice of Transmission Line Impedance

If a flat response curve is to be obtained, damping of the transmission lines must be avoided. One common source of damping of the grid line is the input impedance of the valves. Consequently the characteristic impedance of the line should be considerably less than the input resistance of the valve at the highest frequency at which it is desired to work. The input resistance of a Z77 at 200Mc/s is approximately 200 ohms, so that a grid line of 75 ohms characteristic impedance was chosen. This choice also enabled the amplifier to be fed straight from a standard 75 ohms coaxial cable.

Clearly the voltage gain of one stage will be a function of the characteristic impedance of the anode line. Now the characteristic impedance of a T-section filter falls as the frequency increases while the reverse is true of a π-section. Usually it is preferable for a response curve to rise towards the high frequency end rather than fall as it is a relatively simple matter to reduce the high frequency response. By using a π-section anode line it is possible to partly offset the fall in high frequency response which occurs owing to the valve input impedance damping effect. It can be shown[1] that the response curve is improved if there is positive mutual inductance between adjacent sections of the grid transmission line. By winding the transmission lines in the form of continuous helices

Fig. 5. Frequency response of amplifier shown in Fig. 4



a certain amount of mutual inductance between sections is obtained.

Design of a Single Stage Amplifier

It has been found in practice that Osram Z77 have an upper frequency limit of approximately 200Mc/s.

Let us consider designing a single stage amplifier which is to have a response reasonably flat up to 170Mc/s. Lines having the same velocity of propagation have necessarily the same cut-off frequency.

Cut-off frequency

$$f_c = \frac{1}{\pi\sqrt{LC}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

L = Inductance per section

C = Capacitance per section

Z77 VALVE CONSTANTS

$V_a = V_{sc} = 250$ volts

$I_a = 10$mA

$g_m = 7{\cdot}5$mA/volt

$C_{in} = 7$pF

$C_{out} = 4$pF

Let us assume that stray capacitance per section to earth = 2pF.

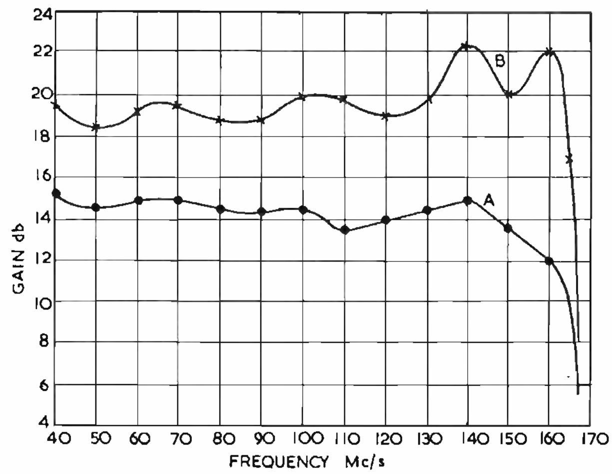


Fig. 6. Effect of terminating the anode line at one end only

ANODE LINE. To obtain maximum gain the characteristic impedance of the anode line should be a maximum

$$Z_o = \sqrt{L/C} \quad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Capacitance per section should be kept to a minimum.

Now minimum capacitance per section = C_{out} + 2pF = 6pF.

From (1) $L = \frac{1}{\pi^2 f_c^2 C} = 0{\cdot}58\mu$H

In order that the amplifier should take up as little room as possible the valves should be as close together as is practicable, i.e., 1in. apart. Thus, one section of transmission line should be 1in. long. Satisfactory results were obtained by making self-supporting helices out of 18 S.W.G. copper wire and making the inside diameter 9/16in.

$0{\cdot}58\mu$H per section corresponds to a 9 T.P.I. helix of the above dimensions

$Z_o = \sqrt{L/C} = 340$ ohms

GRID LINE. To avoid damping and also for convenience $Z_o = 75$ ohms. Now $f_c = 170$Mc/s.

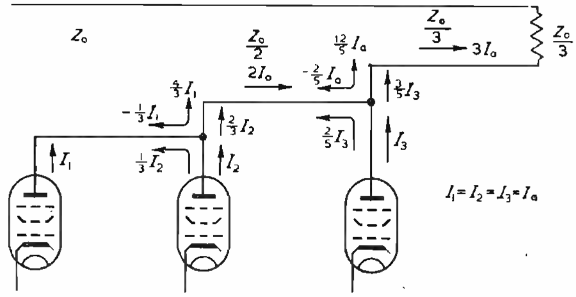


Fig. 7. Current distribution in a tapered anode line

From (1) and (2) $C = \frac{1}{\pi f_c Z} = 25$pF

and $L = Z_o^2 C = 0{\cdot}14\mu$H.

$0{\cdot}14\mu$H per section corresponds to a 3 T.P.I. helix. As the valve capacitance + stray = 9pF, 16pF capacitance must be added from each grid to earth.

Fig. 2 shows the response curve obtained with a six section amplifier constructed to the above design. The termination of the lines is illustrated in Fig. 3. The point of connexion of the terminating resistor and trimming capacitor was adjusted for optimum and also the value of the trimming capacitor.

If more than six sections are used in one such stage the response curve will be found to fall off before cut-off is reached. It is interesting to note that the theoretical voltage gain = $ng_m Z_o/2$ = 7·65 times = 17·7db (assuming g_m = 7·5mA/volt).

Two Stage Amplifier

When two stages are to be cascaded either the grid line of the second stage has to be of the same impedance as the anode line of the first, or an impedance matching device has to be included. The second method presents several difficulties and the first has been found quite satisfactory.

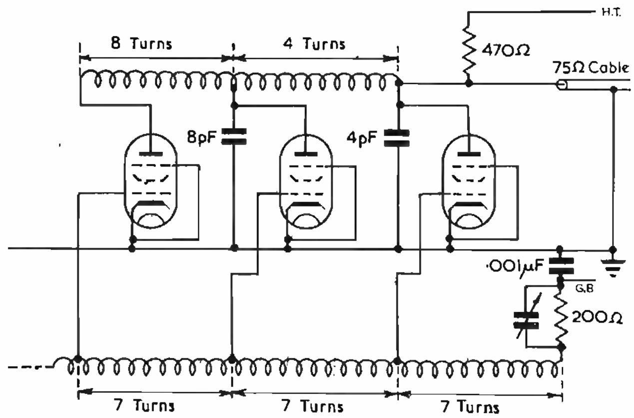
A circuit is shown in Fig. 4. As before, the first grid line has an impedance of 75 ohms. The anode/grid line has an impedance of 200 ohms. and the final anode line 340 ohms. It was found that four Z77 valves was the maximum that could be connected to a grid line of 200 ohms impedance and still maintain a response flat up to 170Mc/s. (It is necessary in the first stage to add capacitance between anode and earth as the input capacitance of the Z77 is higher than the output capacitance.)

The response curve is shown in Fig. 5.

Voltage Doubling in the Anode Line

It is possible to increase the gain of an amplifier by

Fig. 8. Tapered anode line output stage



removing the terminating resistor from one end. Let us consider an amplifier whose delay time is short compared with the period of its cut-off frequency. If the anode line is open-circuited at the input end, signals which travel towards this end will be totally reflected and will arrive at the output very nearly in phase with the true output signal. This would result in the voltage gain being approximately doubled. It has been found that even amplifiers which have a delay time of the order of the period of the cut-off frequency exhibit this voltage doubling effect when one of the anode line terminations is removed. The response curves in Fig. 6 were taken with a six section single stage amplifier employing a 220 ohms anode line. Curve A shows the anode line terminated correctly at both ends, and Curve B the anode line correctly terminated at the output end only.

The Output Stage

It is often required to step the output impedance of the amplifier down to, say, 75 ohms so that the output signal may be fed through a coaxial cable. This may be achieved by several methods:

(a) CATHODE-FOLLOWER

A cathode-follower having an output impedance of 75 ohms and a load of 75 ohms has inevitably a gain of considerably less than unity. Furthermore, the signal handling capacity of such a stage is severely limited. For example, an A1714 triode operated at g_m = 10mA/volt draws an anode current of about 14mA and produces a gain = 0·5 approx. Even if it were possible to swing the anode current between cut-off and 28mA the voltage developed across the 75 ohms load is 2·1 volts peak to peak. In practice the maximum output voltage is considerably less.

(b) AMPLIFIER WITH 75 OHMS LOAD

A single valve with a 75 ohms resistive anode load having a sufficiently low input and output capacitance is not really practicable. A distributed amplifier with 75 ohms anode line can be improved upon by (e) (below).

(c) WIDEBAND TRANSFORMER[4]

One wideband transformer has been constructed and tested having a reasonable response up to 150Mc/s. The method inherently gives a voltage loss.

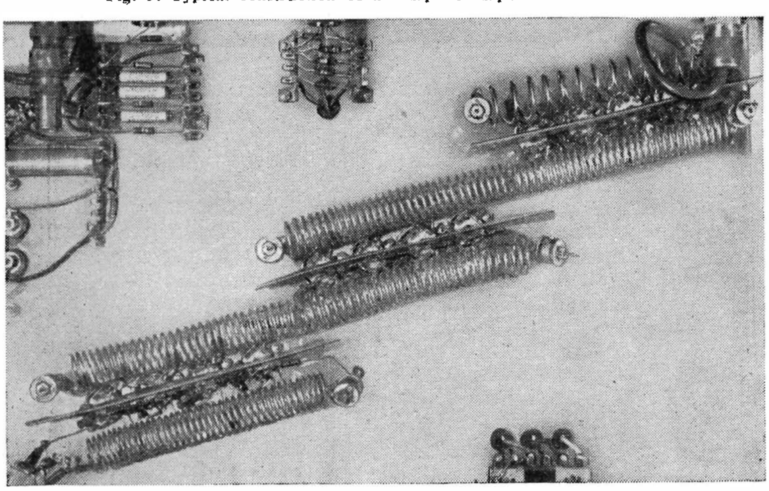
(d) A RESISTIVE PAD

This naturally produces a large loss.

(e) DISTRIBUTED AMPLIFIER STAGE EMPLOYING A "TAPERED ANODE LINE"[5]

This method, which often employs several valves, usually

Fig. 9. Typical construction of a complete amplifier



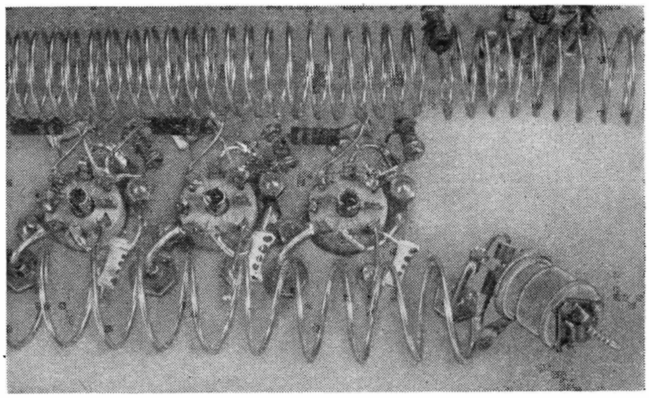


Fig. 10. Close-up view of part of Fig. 9
(Screen between line has been removed)

has a voltage gain greater than unity. Valves are connected with their grids at equal intervals along one transmission line. The anode line takes a tapered form, the first section having an impedance of Z_0, the second $Z_0/2$, the third $Z_0/3$, and so on. The line is open-circuit at the left-hand end. Let us consider the A.C. currents set up in the tapered line when the input signal causes current I_a to flow through each valve. At the junction of two transmission lines of characteristic impedance Z_1 and Z_2 the current transmission coefficient (from Z_1 to Z_2) $= \dfrac{2Z_2}{Z_1 + Z_2}$ and the current reflexion coefficient $= \dfrac{Z_2 - Z_1}{Z_1 + Z_2}$

By applying these formulæ it can be shown that the current distribution is as in Fig. 7, i.e., the voltage along the line is constant.

The circuit in Fig. 8 was designed to have a cut-off frequency of 150Mc/s. As before, the valve bases were placed 1in. apart, thus each line section is 1in. long. Again the inside diameter of the helix was 9/16in. Theoretically the characteristic impedance of the first section of the line is 260 ohms and the second 130 ohms. Thus, the output impedance is 65 ohms. In practice it was used to feed into 75 ohms cable and the response was well maintained up to 140Mc/s, falling away above this.

Circuit Layout

The photographs, Figs. 9 and 10, show the method employed in construction. Feed-through capacitors are employed for all supplies distributed above the chassis. Where additional capacitance was added between grid and earth it was found necessary to use a separate earth tag for this capacitor. Using the same tag as for the cathode lead caused a tendency for each valve to oscillate. Standard ¼ watt carbon resistors were found to be quite satisfactory as terminating resistors.

Acknowledgment

This work has been carried out on behalf of the Ministry of Supply. The author wishes to thank the Chief Scientist, Ministry of Supply, for permission to publish this paper.

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The Activities and Equipment of an Industrial Electronics Laboratory

(Part 4)

By G. H. Hickling,* B.Sc., A.M.I.E.E.

Special Purpose Electronic Instruments

In addition to the basic types of electronic circuit that were discussed in Part 3, innumerable special purpose electronic instruments have been designed, some of which will find a place in most industrial laboratories or in the factories with which they are associated. The circuit techniques used in many of these are already well documented. Space, in any case, precludes more than a very brief review here; the references given will, however, suffice to enable the reader to follow up any on which further information may be desired.

In this category electronic voltmeters, component testers and electronic frequency meters or tachometers are almost universally needed. Counters, either mechanical (electrically operated) for up to 15 counts per second, or of the purely electronic type[58-63] for higher speeds; radiation meters; electronic thermostats and temperature indicators; each find many useful applications, while noise meters incorporating specially calibrated microphones and amplifiers, with special audio "weighting" networks[64] are a further frequent requirement. These devices have obvious direct applications to measurement problems. Electronic relays, including double and multiple "beam switches"[58, 65-6] and time-base circuits[21, 48, 67-9] (both "free running" and "triggered" types) for use with cathode-ray oscillographs are other devices used indirectly in many investigations in the electronics laboratory. The magnetic sorting bridge[1] is yet another example, to which reference has previously been made.

Various different types of circuit are in common use for the particular special application of measurements with variable-capacitance gauges, of which the general utility was noted in the first part of this series. The essential requirement of such equipments is to detect small percentage changes in the value of the gauge capacitance, itself of the order of a few picofarads only and generally many times smaller than the associated lead capacitance. Three of these circuits are thought to be of sufficient interest to merit somewhat fuller discussion.

Capacitance Gauge Circuits

Type I. One much used circuit makes use of the discrimination of a selective R.F. tuned circuit, adjusted slightly off resonance, for small changes of capacitance or of frequency. The gauge may be connected across the tuned circuit, fed from a stable constant frequency R.F. source, so as to produce amplitude modulation of the signal which is then rectified and further amplified in a direct coupled amplifier; or, in the preferred F.M. system,[15,16,17,70] it may be used to modulate the frequency of the oscillator, changes of gauge capacitance being then made evident by means of a selective frequency discriminator (Fig. 28). The latter arrangement has the advantage that the frequency-modulated signal can, if desired, be transmitted an appreciable distance to the observing point. Furthermore, by including a limiter stage as shown, any unwanted amplitude modulation or pick-up voltage is rejected before reaching the discriminator; and the latter may be made as sensitive as required by cascading several fixed frequency tuned stages, by the use of a phase discriminating demodulator,[15] or if necessary by a method of frequency multiplication.[70] An important feature of these circuits is their ability to give static or D.C. response, thereby greatly facilitating calibration.

Instruments of this type are frequently used with variable-gap type electrodes specially made for each application. Their usefulness in such cases may be increased by making them direct-reading in displacement units. This can readily be done if electrodes of standard areas are adopted, and provided that the mean gap—corresponding say to mid-scale reading—is always set initially to the appropriate

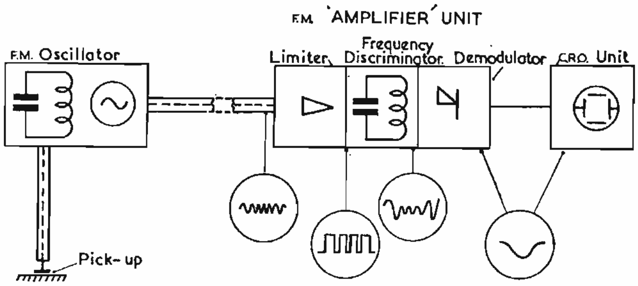


Fig. 28. F.M. capacitance gauge systems

value. Suitable scale factors for different ranges may then be used with electrodes of proportionate areas.

In the capacitance gauge recorder which was shown in use in Fig. 5 of Part 1, as in some others,[16] a complete circuit of this type is built as a self-contained unit. In another commercially available outfit suitable for measurements at more remote and inaccessible points, on the other hand, the oscillator is supplied as a separate battery-operated unit for location close to the gauge position, while very stable mains powered F.M. "gauge heads" have recently been made in the laboratory.

A technique which has been found valuable for obtaining increased sensitivity with the foregoing class of equipment and which has not, so far as the author is aware, been published previously, is that of tuning the gauge capacitance by series inductance. This may be done with a small "tuning box" (Fig. 29(a)) arranged to plug in between the gauge and its connecting cable. In addition to the inductor, two trimmer capacitors are provided for adjustment of the "effective inductance" and the earth capacitance. As will be seen from the typical response curves given (Fig. 29(b)), an increase in sensitivity of some 30 times is readily obtainable, with good linearity over a useful working range. This device permits the use of smaller electrodes and/or larger working gaps for a given range of movement.

* C. A. Parsons & Co., Ltd.

TYPE 2. A second class of capacitance gauge detector circuit, capable of very much greater sensitivity, comprises an A.C. bridge circuit using inductively coupled ratio arms.[71] The form shown in Fig. 30, used in an aircraft altimeter[72] and also in a commercial wide-range capacitance bridge, has the special feature that it measures direct capacitance between two points, unaffected (within limits) by that of either point to earth. Its operation is made clear by considering the two capacitance currents fed through C_x (the unknown) and the balance capacitor, into the detector or output transformer. Assume for simplicity that both transformers have the same tapping ratio on the H.V. side, of say $N:1$. The two currents, determined by the capacitive reactances and applied A.C. potentials and fed in the same phase into opposite ends of the detector transformer, will then precisely balance one another when the capacitances are in the ratio $1:N^2$. In these circumstances no voltage will appear across the detector; but increase or decrease of C_x will result in output voltages of corresponding phase and proportionate amplitude. With phase sensitive rectification, this output can be utilized to readjust the balance

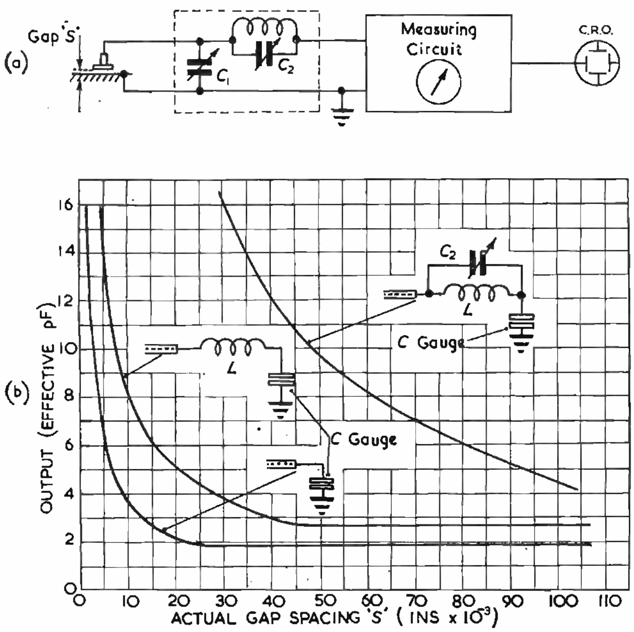


Fig. 29. Series tuning of Capacitance gauges

capacitor automatically, using for this component a capacitor vane mounted on a normal meter type movement.[72]

This type of equipment is used to detect changes of the order of 10^{-5}pF, despite the presence of shunt capacitances to earth of the order of 10^8 times greater. The latter, being effectively shunted across either the oscillator or the detector, though they may cause slight loss of sensitivity, do not affect the balance. Fig. 31 shows a variation on this type of circuit for measuring small values of capacitance to earth. An intermediate screen in the connecting cable (see inset) is arranged again to eliminate the cable capacitance from the measurement.

TYPE 3. Yet another approach to the same problem is shown by Fig. 32. This circuit utilizes a cathode-follower in the input to the detector amplifier. Besides offering a high input impedance in itself, this serves to maintain the potential of a screen enclosing the entire input circuit—including the connecting lead—at a potential very close to that of the detector electrode itself.[42] With perfect cathode-follower action this would, in effect, entirely eliminate the capacitance and leakage of both the cable and measuring circuit. The simple triode cathode-follower, as shown, effects a very useful increase in sensitivity: but in attempts to approach more nearly to this ideal condition, use has been made of a pentode valve as a high impedance cathode load, and of an auxiliary cathode-follower in the anode circuit to reduce the effect of anode/grid capacitance.

The gauge may either be connected in an A.C. bridge circuit as shown, or it may be D.C. polarized through a high value resistor. The latter method has been used to advantage in the writer's laboratory in a vibration control unit for fatigue testing, in which a signal derived from a

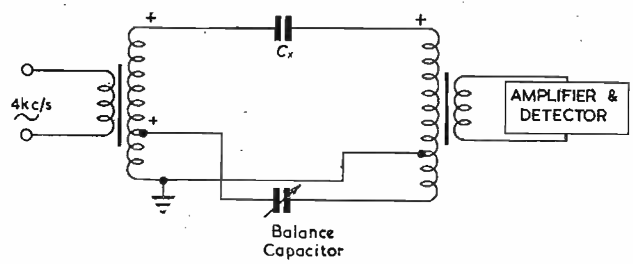


Fig. 30. Capacitance bridge circuits employing inductively coupled ratio arms

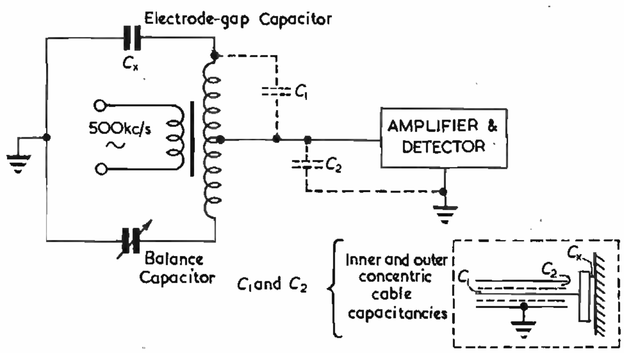


Fig. 31. As Fig. 30—Circuit for capacitance to earth

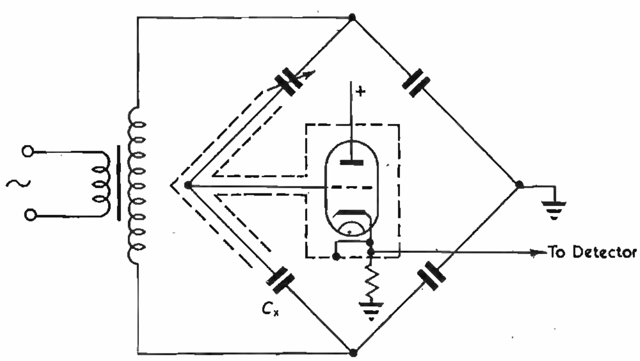


Fig. 32. Capacitance bridge circuit with cathode-follower coupled screen

pick-up electrode close to the vibrating specimen is used to control the input to the driving power amplifier. This circuit is shown in Fig. 33. A limiter stage is incorporated to stabilize the signal amplitude, followed by an A.V.C. stage so designed as to give *increased* driving power if the vibration amplitude *decreases*. A power ratio of about 10:1 is obtained for an input signal variation of 2:1 or less.

Recording Equipment

Measuring systems in general have been said[73] to consist of the detector, the "intermediate means" and the "end device" or indicator. The first two of these groups have

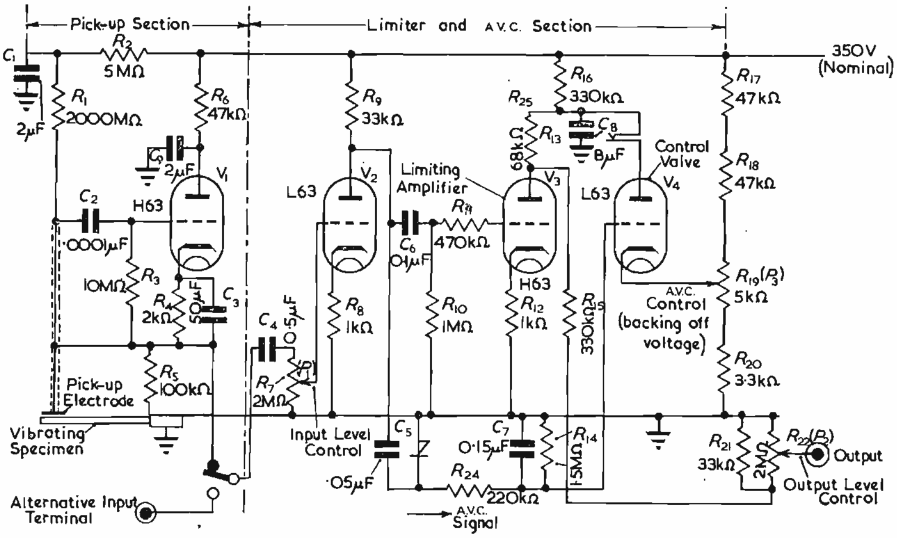


Fig. 33. Vibration feedback control amplifier

now been discussed at some length, but we have as yet given no consideration to the last and very important section of our laboratory equipment. For most purposes, the " end device " comprises either an indicating meter or some form of recording device. The former calls for no comment here. In the latter category, however, there are quite a number of types, which may usefully be classified according to the rapidity of the transient phenomena which they will record, viz:—

(a) Standard inking type pen recorders.
(b) High speed pen recorders.
(c) Optical galvanometer recorders (Duddell).
(d) Cathode-ray tubes with moving film cameras.
(e) High speed cathode-ray tubes with electronic time-bases.

Instruments in class (a) serve a very useful purpose but have long response times of the order 1 to 5 seconds. They require normally about 5mA for full scale deflexion. There are also well-known variants, of the multi-point " dotting " type—either " potentiometric " or galvanometer operated—with a recording time sequence normally of 30 seconds per point; minimum about 10 seconds. In class (b) several recorders are available with response frequencies up to about 100c/s. One (American) is crystal operated with an inking pen, while another, of British make, employs up to four galvanometer type movements and an electrically energized stylus using special carbon-backed (" teledeltos ") paper. It is believed that a Swiss instrument is now available giving direct-writing chart records up to over 500c/s. All of the foregoing types have the particular merit of giving immediately available permanent records.

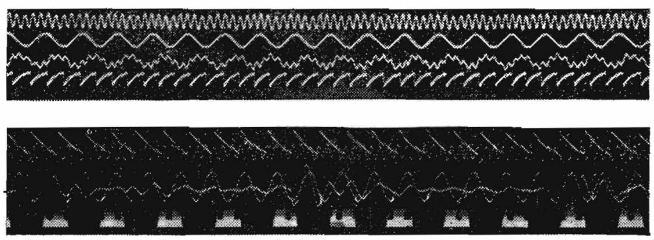
Recorders of class (c) extend the frequency range to 800 or 1,000c/s, employing photographic recording by means of a beam of light, and are generally classified as " oscillographs ". A number of self-contained multi-channel recording cameras of this type are on the market. Finally the cathode-ray oscillographs (classes (d) and (e)) extend the range to the highest frequencies likely to be met in industrial work. The limitation in class (d) is normally the speed of film movement (dependent on the camera), while in class (e) it is the photographic writing speed—up to 3 metres-microsecond being attainable on the higher voltage sealed tubes.

Each class of recorder has its own particular field. Those of the moving-coil type (in any of the first three classes) can be run directly from amplifiers—A.C. or D.C.[74, 75] One high speed type recorder requires a peak current of about 40mA for full scale response, but for A.C., with transformer matching, this is no problem; for D.C. it is readily obtainable from suitable valves.

The optical galvanometer type oscillographs are usually built into the camera—of either continuous feed or drum type. Cathode-ray tubes, on the other hand, are more usually employed with separate recording cameras. In either case, reliability in this part of the equipment is very necessary. Fig. 34(a) shows a laboratory-built oscillograph camera which enables either moving film or single frame exposures to be made at will without any adjustment to the camera. A multi-speed shutter (operated at rear) and a built-in time marker are other features provided. Such cameras can, incidentally, be used for recording directly various mechanical displacement phenomena, without any additional apparatus.[76]

Multi-channel cathode-ray recording equipments may utilize several separate tubes, double or multiple-beam oscillographs (in the U.S.A. multi-gun tubes for up to 12 ways are now available), or again electronic beam switches may be employed. The latter are available giving up to 5 traces on a single-beam oscillograph. A convenient method is to use 2-way beam switches in duplicate with a double-beam tube, giving a 4-trace record as in Fig. 34(b). The switching rate may be controlled from a known frequency source to provide accurate time marking.

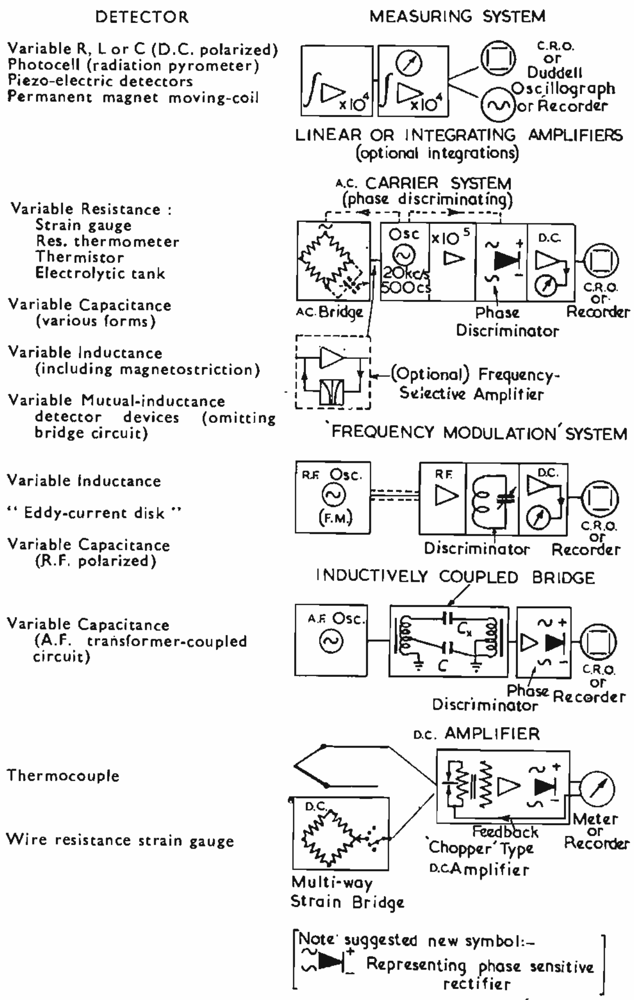
Fig. 34. (a) An oscillograph camera. (b) Typical moving film recordings



Electronic Measuring Systems

Having now dealt with the essential component parts of electronic measuring systems, it is logical to give some thought to the make-up of such systems as a whole, and to consider the more general factors involved in the selection of equipment for the laboratory. To this end it is proposed to develop further the theme suggested in Part 2 that, guided by a knowledge of the available detector devices, it is possible to build up on the "unit" principle a complete system of measuring and recording equipments to cover almost any research problem. Apart from effecting considerable economy, such a policy, aided by careful planning, greatly increases the efficiency of the laboratory since the research engineer can have at his command—and immediately available—the tools necessary to carry out any investigation which he may be called upon to make.

Table 2



It will be recalled that Table I in Part 2 showed how detector devices for many widely different types of measurements depend on only a few basic electrical elements—variable resistance, inductance or capacitance, or generators of E.M.F. such as the moving-coil and piezo-electric detectors. Table 2 shows the relation of these devices to the appropriate electronic measuring systems. In this Table an attempt is made also to show how a comparatively few basic measuring systems, built up from a few standard unit instruments, suffice for use with many different types of detector element and to cover a still greater number of measurement applications.

At the same time, by planning equipment on the unit principle, a very desirable flexibility is preserved. Innumerable variations are possible on the typical systems illustrated, to meet the requirements of particular tests. Such variations will depend on the method of presentation desired (e.g., indicating meter, oscillograph or recorder), on the need for single or multi-channel indication, and more particularly on the circumstances of the actual measurement to be made. Thus measurements with resistance strain gauges, for example, may be made without recourse to electronic methods at all if purely static; with an A.C. polarized bridge and phase discriminating amplifier where static and low frequency fluctuating strains are combined; or by direct amplification with D.C. excited gauges if only high frequency or "impulsive" strains have to be measured. In the first instance, again, a large number of gauges can generally be measured successively using a single measuring channel (in which case a recorder is advantageous), whereas for transient phenomena, one channel for each active gauge is normally required. The A.C. carrier system, incidentally, is almost essential where strain gauges may have to be used in strong A.C. electromagnetic fields.

Clearly it is not possible to discuss here in detail the make-up of the many test circuits which may be used, but it is hoped that the schematic representations given in Table 2 may prove useful in suggesting appropriate arrangements for use in specific cases which may arise in practice.

A desirable principle to be borne in mind in the design of electronic measuring or recording equipment is that all individual instruments and amplifiers should be directly calibrated in voltage sensitivity or gain (and, if possible, made self-checking) so that quantitative measurements can be obtained with a complete assembly of equipment without recourse to overall calibration on every occasion. Pick-up devices should be adjustable, and periodically standardized, to a convenient output voltage level per unit of the quantity measured.* Oscillators should have output voltage metering.

A further very useful method of ensuring satisfactory overall calibration, and more particularly good transient response, is that of overall negative feedback. An instance of this is the self-balancing capacitance bridge referred to earlier[72]; others occur in the double-beam infra-red spectrometer illustrated in Part 1 or again, for example, in the use of a hot filament reference source for comparison with the target temperature in the case of a radiation pyrometer.

(To be continued)

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* *In the case of crystal vibration pick-ups, for example, this is readily done by means of a small parallel trimmer capacitor.*

Some Recently Developed

Cold Cathode Glow Discharge Tubes

and Associated Circuits

(Part 1)

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

The use of the glow discharge as a means of producing a voltage reference which is insensitive to current variation has been widely known for many years. However, the recent advances which have made it possible to extend the scope of application of the glow discharge are not, in general, yet appreciated. The aim of this series of articles is therefore to outline some of the major design features of new types of cold-cathode glow discharge tubes and, at the same time, to provide some indication of the way in which they are being applied to perform useful functions in diverse kinds of circuits.

THE suitability of the gas-discharge gap as a two-position device for use in counting chains was first recognized by Wynn-Williams, who presented a paper[1] to the Royal Society in 1931 disclosing some basic circuit arrangements using hot-cathode thyratrons. Much of his technique proved to be fundamental and is still in use at the present time. Later, designers recognized the advantages of the cold-cathode discharge, which are the absence of heater supplies and the visibility of the glow, and several new tubes and circuits followed. A paper on cold-cathode tubes as circuit elements in 1939 showed counter circuits based on the original Wynn-Williams techniques which made use of the first quantity-produced three electrode trigger tube.

Today, with the tendency towards computing and devices which act in a similar manner, the gas trigger tube and multi-electrode counting tube have become established as convenient and reliable circuit elements which cover a very wide field of potential application.

The Basic Properties of Cold Cathode Trigger Tubes

In the discussion which follows it is the intention to give the reader brief descriptions of some of the physical processes which take place in a three element gas discharge tube. Each of the basic properties will be discussed as a separate entity, and by considering them in conjunction with each other it is quite easy to see how certain characteristic requirements may conflict with each other. This has led to the development of a number of different types of commercial tubes, each of which has been designed to meet specific requirements.

Basically, the trigger tube when used as a circuit element is a one-way switch, in which the ultimate low impedance connexion is effected by the application of a positive pulse through a high impedance to the trigger electrode. A positive pulse is generally used to produce a low current discharge in the trigger cathode gap, this then causes the main anode cathode gap to conduct. The potential at which the main gap maintains the discharge is determined by the cathode material and type and pressure of gas used in the tube.

It is usual in cold-cathode gas-filled tubes to make use of the inert gases such as helium, neon, argon, etc. and various mixtures which are chosen best to suit the particular type of tube under development. The inert gases are so selected because of their various discharge properties and because they are inert, thus removing any risk of chemical action with other important parts of the tube such as the cathode and anode. These atoms do, however, have the property of being able to exist for considerable periods in excited states, in which condition one of the electrons in the inner orbits may have been raised to an outer orbit. In this condition the atom is said to be in a metastable state, and the excited electron either returns to its correct level, returning the metastable atom to its ground state, or it may be further excited to a higher level by a second collision. If the energy imparted on the second collision is sufficient, then the electron may be removed and the metastable atom will then have been ionized. In this case it is easy to see that the energy required to ionize a metastable atom is less than that required to ionize a similar atom in its ground state. This particular feature is made use of in certain mixtures where metastable atoms of one gas can directly ionize the atoms of a second gas,[2] leading to lower breakdown potentials, which is a feature which is often desired in cold-cathode gas discharge tubes.

The maintaining potential of the main gap has here been used to categorize the present commercial tubes. One class has a maintaining potential in the region of 80-100 volts, and a second class contains tubes whose maintaining potentials are between 150 and 180 volts. It is proposed to make a distinct division between these two classes, since this parameter determines certain other basic properties which will shortly be discussed.

The first class of tubes is that which makes use of a cathode material which has a low work function. A number of commercial tubes, such as the G150/2D which has a barium cathode, and the K3A which has a potassium cathode, are good representatives of this class. All tubes in this class are restricted to low speed applications because of their inherently long deionization times, and at least one in the second class, the G1/370K, has been designed for the express purpose of providing a cold-cathode trigger tube capable of working at considerably higher speeds. Since it is largely the question of speed which indirectly determines the choice of cathode material, and hence into which range of maintaining potential a tube falls, it is proposed to discuss the physical processes of "deionization" first.

Deionization

The normal breakdown potential of a gap can be considerably reduced[3] by the presence within the gap of a

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

large number of ionization products such as electrons, ions and, when the inert gases are used, metastable atoms. This reduction in breakdown can be described as "ionization coupling" resulting from self priming, and has been designated by the symbol ϕ which is defined as follows:

$$\phi = \frac{V_{BN} - V_{BP}}{V_{BN} - V_{M}} \times 100 \text{ per cent} \quad \ldots\ldots\ldots (1)$$

where V_{BN} is the normal breakdown potential,
V_{BP} is the primed breakdown potential,
V_{M} is the maintaining potential.

If we consider the conditions in a gap at the point at which the discharge ceases, it will be appreciated that there are large numbers of charged particles in transit across the gap and that until these have been removed a high degree of self priming exists which may cause the discharge to be reinitiated on the reapplication of the working potential to the anode. If, as is generally the case, the discharge had been extinguished by a reduction of the anode potential below the maintaining potential of the gap, the time which must elapse before the potential may be raised above the maintaining potential is entirely dependent upon the time taken for the ionization products to decay below a certain level. To permit a direct comparison of various tubes and to provide a figure of merit, the deionization time has been arbitrarily defined as the time which must elapse following a D.C. discharge of maximum rated current, extinguished by means of a rectangular pulse applied to the anode, before 90 per cent of the maximum working voltage may be reapplied across the gap without reigniting the discharge. The base of the extinguishing pulse shall be 20 volts below the V_M of the main gap and all other electrodes in the tube may be at potentials within their working range. For example, the maximum rated current of the G150/2D is 20mA with a V_M of 70 volts, and the maximum working voltage is 150 volts. In accordance with the above definition the deionization time is 12 milliseconds, and a square pulse applied to the anode which extinguishes the discharge needs to be at least this length if the discharge is not to be reignited on its trailing edge when an anode potential of 135 volts is reapplied.

Returning to the discussion of the processes involved in deionization, since electrons have a mobility which is far in excess of that of ions and some field is always in existence within the tube, the electrons are removed from the gap in the first few microseconds following the termination of the discharge, and it is the time taken to remove the ions and metastable atoms which extends the deionization time. In the case of the low work function cathode type of tube, it is, in general, not possible to include in the gas mixture deionizing agents which reduce metastable atoms to their ground states, since such mixtures lead to a destruction of this type of cathode surface. Hence, the deionization times of such tubes are dependent upon the longest lives of the metastable atoms of the inert gases used. When a metastable atom has energy which is in excess of the work function of a metal, the energy released by the metastable colliding with the surface of such a metal may be sufficient to release electrons. Furthermore, photons, which may be released when metastables collide with other gaseous particles, also have sufficient energy to produce photo-electrons from the same metal surface. Hence if a metal of low work function is used for the cathode surface, metastable atoms may, at the termination of their lives, produce a supply of electrons which are the most active agents in the "self" priming mechanism. Since metastables are neutral particles, they can only be removed by a deionizing agent, and without this, their lives are determined by natural processes over which there is no control.

Metastable atoms may have energy levels as high as 10 volts, but these have comparatively short lives, since they rapidly decay to the lower levels in the order of 3 or 4 volts. It is these which have relatively low energy levels that have the longest lives. For example, Argon is known to have a metastable state whose life is 10^{-3} seconds. Since, as described above, secondary electrons can be produced from a metal whose work function is lower than the metastable level, the deionization time of a tube using such a metal as a cathode is extended to be at least as long as the natural life of the metastable atom.

The work function of pure nickel or molybdenum is approximately 5 volts, while that of the activated cathode tube is approximately 2·5, so that under identical conditions the deionization times of tubes using pure nickel cathodes are shorter than those of the activated cathodes. However, the use of pure nickel as a cathode can be turned to greater advantage by including in the mixture a suitable deionization agent which rapidly removes any metastable atoms left at the end of a discharge. This has been done in the G1/370K and a percentage of hydrogen has been included in the gas mixture for this purpose. Hydrogen relies upon its molecular dissociation for its deionizing properties, since when a metastable atom collides with a molecule of hydrogen the latter absorbs 4·2 volts of energy on dissociating and reduces the metastable atom to a level 4·2 volts below its previous level. With suitable concentrations of molecular hydrogen metastable atoms are therefore either returned after a number of collisions to their ground states, or levels below 4·2 volts. Hydrogen

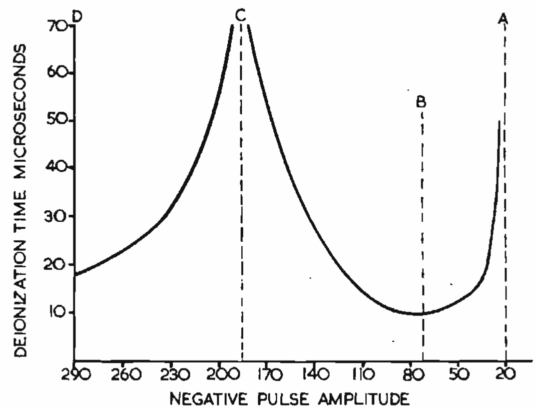

Fig. 1. Curve showing deionization time as a function of extinguishing pulse amplitude

may therefore be employed as a deionizing agent with cathodes whose work functions are higher than its dissociation level. The deionization time in the G1/370K is therefore independent of the lives of metastable atoms, and consequently depends on the time taken for the removal of positive ions from within the gaseous volume.

The following experiment was conducted in order to obtain experimental confirmation of the above concepts of deionization. Using a pair of plane parallel electrodes in an atmosphere of neon argon and hydrogen in a valve where the sides of the tube were a comparatively long distance from the discharge, the deionization time of the gap was measured as a function of the amplitude of the negative extinguishing pulse. Square pulses were used and the D.C. level, peak current and conducting period were maintained at constant values. The negative pulse amplitude was then measured in volts below the maintaining potential of the gap and the width reduced until the glow was restruck by the back edge of the pulse. Fig. 1 shows the curve that was obtained of deionization time as a function of negative pulse amplitude, and with the help of this curve the essential process involved may be explained.

As indicated previously, in a tube using pure metal electrodes and including in the gas a suitable deionization agent, deionization depends largely upon the removal of positive ions. Consider the conditions existing in the gap at the end of a discharge. There is a positive ion space charge within the gap and the extinguishing of the discharge consists of its enforced collapse by the reduction of the field applied across the gap to below the maintaining potential of the gap. If this reduction is only a few volts in magnitude, the rate of collapse is slow and correspondingly long deionization times are involved. This is section AB of the curve shown in Fig. 1, and sets the minimum extinguishing pulse amplitude at approximately 20 volts

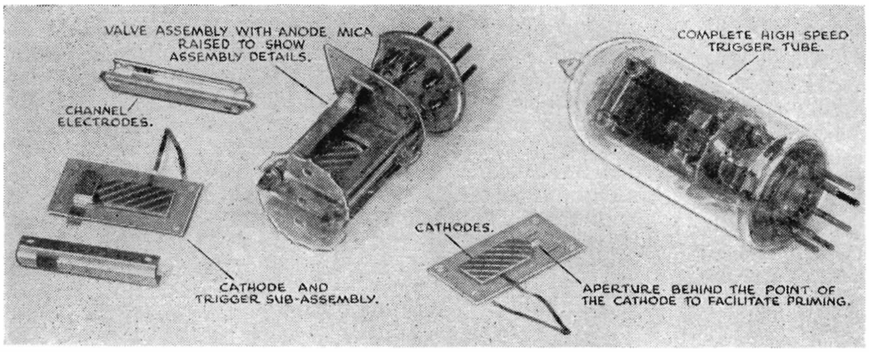

Fig. 2. An exploded view of the G1/370K

below V_M. From that point onwards the deionization time is a measurement of the time taken for the field across the gap produced by the base of the extinguished pulses to reduce the number of ions within the gap to a figure n, below which the gap does not restrike on the reapplication of the anode volts. As the pulse amplitude is increased the field across the gap is reduced and the deionization time becomes longer until, at the point where zero field across the gap exists, a maximum is reached. The peak on the curve at this point is determined by the natural rate of recombination, and is in the order of hundreds of microseconds. A plot of the section BC of the curve in the form of t against d/kX where X is the field due to the base of the extinguishing pulse and k is the positive ion mobility, gives a straight line, confirming that the nature of the process is as described above. A further increase in the pulse amplitude beyond the point of zero field results in the application of a reversed field across the gap and a corresponding reduction in deionization time, as shown in section CD.

This experiment was based on an idealized condition in order to demonstrate the basic process involved in deionization. In practical conditions there are always stray fields due to surface charges, etc., which modify the above concept.

From the above discussion the following design points emerge:—

(1) The diffusion from the main gap during a discharge should be kept at a minimum, since this determines the number of ions which have to be removed from the gaseous volume during the deionization process.

(2) The volume through which diffusion can take place should be restricted to minimize the path lengths of the ions to be removed at the end of the conduction period.

(3) Stray fields, which may oppose the field due to the extinguishing pulse should be eliminated and, if possible, controlled fields introduced.

In the G1/370K,[5] which is illustrated in Fig. 2, the main gap is designed with parallel plane electrodes and is contained in a box-like construction so that the volume through which the ions may diffuse is restricted to a minimum. The anode and cathode are two sides of the box and a pair of "channels" form two other sides. In order to reduce deionization time to a minimum the "channels" should be biased positive to about 150 volts, so that a constant clearing field is supplied which overcomes the influence of stray surface charges and, at the same time, eliminates any variation in deionization time due to changes in extinguishing pulse amplitude. The average figure obtained under these conditions, over the full range of reapplied anode volts, is in the order of 20 microseconds, Fig. 3 shows the variation of deionization time with current for a reapplied anode potential of 330 volts.

This figure represents an improvement in this particular characteristic by a factor of about 500, and has been obtained at the cost of increased operating potentials. It represents the essential difference between the two classes of tubes, and is approaching the ultimate limit which is imposed by the rate at which a discharge can be extinguished.

Although the rectangular pulse has been used for convenience in definition and measurement, it is the exponential extinguishing pulse which is most commonly met in practice. It has been found experimentally that for most types of tube the exponential extinguishing time-constant is perhaps a third or a quarter of the duration of the corresponding rectangular pulse. However, since it is generally necessary for potentials to rise and decay to a maximum extent, the nature of the exponential does not allow very high speed working. For a conventional ring counter the maximum safe counting rate is about one-tength the reciprocal of the defined deionization time.

Transfer Characteristics

TIME FACTORS

The transfer characteristics of a trigger tube describe the properties associated with the transfer of the low current discharge in the trigger cathode gap to full discharge in the main gap. In some circumstances the trigger cathode discharge may continue after the transfer has been

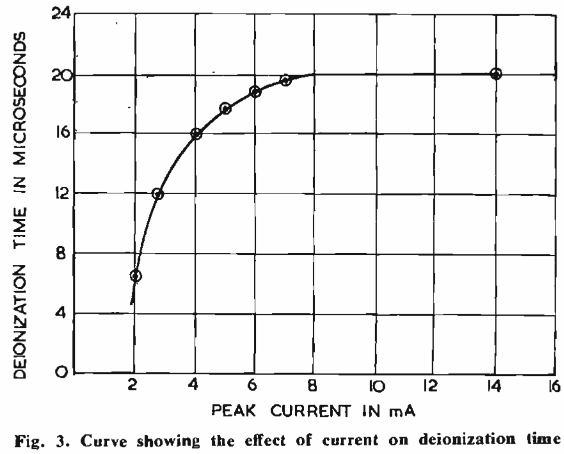

Fig. 3. Curve showing the effect of current on deionization time

effected, but generally this discharge is discontinuous and may be derived from a pulse source, in which case the pulse producing the initial discharge is short compared with the period of the main discharge.

The time taken (T) for the transfer to be effected after the application of the triggering pulse may be expressed as follows:

$$T = t_1 + t_2 + t_3 + t_4 \quad \ldots\ldots\ldots\ldots \quad (2)$$

where t_1 is the trigger cathode statistical delay, which is the time interval between the application of the leading edge of the pulse and the propitious arrival of an electron to start the avalanche associated with breakdown;

t_2 is the time taken from the beginning of the avalanche to the formation of the positive space charge and is termed the formative delay time;

t_3 is the time taken for the trigger discharge to prime and produce a breakdown in the main gap;

and t_4 is the time taken for the current to build up in the main gap.

The statistical time delay t_1 which may exist is of very great importance, since in general it determines the conditions for the first operation after long periods of quiescence. In the case of the tubes described as category 1 statistical delays are generally small when they are operated in daylight or artificial light because of the presence of large numbers of photoelectrons. The glass bulbs used in the manufacture of valve envelopes have a light transmission curve which cuts off at approximately 2,900A, so that barium and potassium cathodes whose photo-electric threshold is approximately 5,000A provide their own priming electrons by means of photo-electric emission. This feature is useful, but can be embarassing when the tubes are operated in strong sunlight and excessive numbers of photo-electrons are produced which lead to spurious breakdowns in the main gap. In the case of category 1 tubes then, the time t_1 may be variable and is dependent upon the external conditions of lighting associated with the tube.

In category 2 tubes, there are no photons available from outside sources, since the photo-electric thresholds of nickel and molybdenum are approximately 2,500A and below the cut-off wavelength of the glass bulb. This necessitates the use of some source of internal priming, and in the G1/370K an independent priming gap has been provided. This is arranged to beam photons into the trigger cathode gap only, so that it does not affect the breakdown potential of the main gap. When this tube is employed with short pulses (15 microseconds) on the trigger it is essential that the priming discharge is continuous direct current, and this is arranged to be approximately 250 microamps. When long pulses are used in the trigger circuit (100 microseconds) and exact timing of the main gap breakdown is not important, it is possible to adjust the value of the series resistance in the priming gap circuit so that the discharge becomes discontinuous and a mean current of a few microamps flows. Under these conditions small pulses of current provide the photoelectrons in the trigger gap and, depending upon the relative time position of the leading edge of the pulse and the squeg pulses in the priming gap, statistical delays up to the length of the interval between these pulses may be encountered. Since the tube is normally used at high speeds it is usual to use a continuous direct current in the priming discharge, thereby reducing the value of t_1 in Equation (2) to zero. It should be appreciated that this type of priming provides a greater degree of control over the conditions within the tube than that made use of in category 1 type of tube where the arbitrary conditions of external illumination in effect control the degree of priming available.

The second factor in Equation (2) t_2, is the formative delay time, and is determined by the geometrical design of the trigger cathode gap and the pressure and type of gas used. Fig. 4 shows a typical Paschen curve in which the breakdown potential is plotted as a function of the product of the gas pressure (in mm of Hg) and the gap length (in mm) and the point of minimum breakdown is given by the point 0. The following equation gives the relationship between the formative delay time t_2 and the normal breakdown:

$$t_2 = \frac{k_1}{1/V_B - 1/V} e^{-k_2/V} \qquad \ldots\ldots\ (3)$$

where k_1 and k_2 are constants determined by the geometry and type of gas and pressure used,

and V is the over voltage applied in the form of a pulse, and is a voltage in excess of V_B.

This equation shows quite simply that for pulse operation, as is normally the case, the shorter the pulse width (t_2) the greater the over voltage necessary to produce breakdown in that time. It is also obvious that it is highly desirable to design for a minimum V_B so that the over voltages necessary will be as small as can be achieved. All trigger-cathode gaps in all tubes are therefore designed to coincide with the

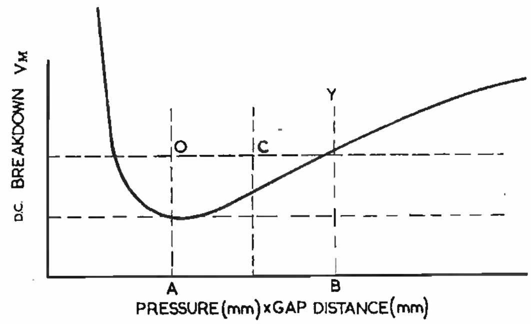

Fig. 4. Typical Paschen curve

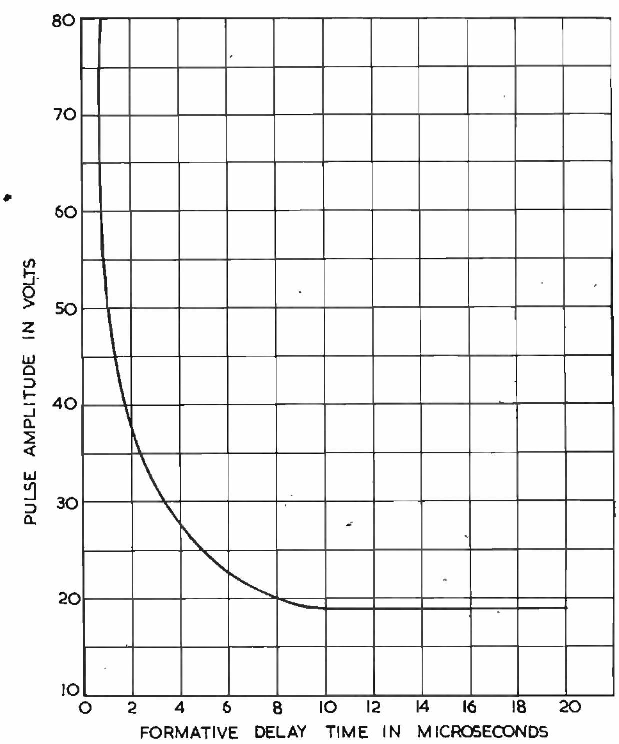

Fig. 5. Curve showing the effect of pulse amplitude on formative delay time

minimum point on the Paschen curve as indicated. In most tubes a large physical area where this condition exists is generally provided without attention to the requirement of providing consistent operation under specified conditions. Since it is the discharge between the trigger and cathode which primes and produces breakdown in the main gap, any variation in the position of breakdown in the trigger cathode gap is reflected in a variation in the factor t_3 of Equation (2). The time taken for transfer can be eliminated if the trigger is arranged to be inside the main gap so that the mechanism of transfer excludes a new formative delay time and merely depends on the rate of spread of the glow from the trigger cathode gap into the main gap.[6] This

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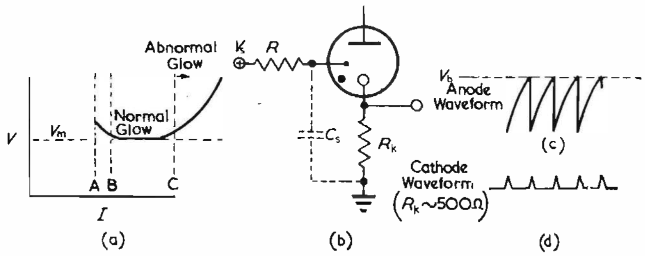


Fig. 6. Trigger gap operation

technique has been used in the G1/370K so that in that particular tube t_3 has been reduced to zero.

The factor t_4 in Equation (2) is obviously very dependent upon the impedance in series with the main gap, and in addition, the geometrical design of the main gap is of importance in this connexion. When a discharge is taking place between two electrodes there is always a certain loss of current by diffusion, and this also takes place during the build up of the discharge. The loss by diffusion is a minimum when a parallel plane electrode geometry is used, and this type of geometry should be employed to keep t_4 at a minimum.

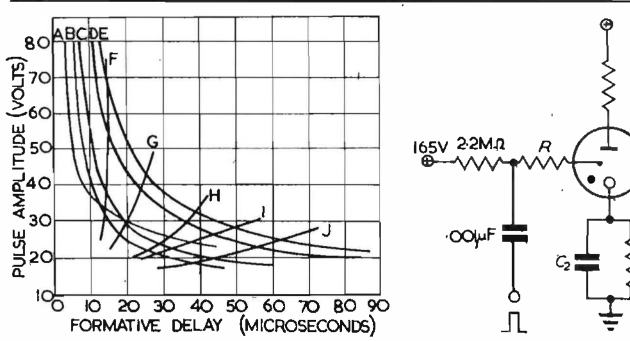
The various design criteria evolved in the preceding discussion have been used in the G1/370K, with the result that after the formative delay of the trigger-cathode gap the total time required for a discharge to form in the main gap is of the order of 0·5 microseconds. Fig. 5 shows a curve of formative delay time as a function of applied voltage in excess of the recommended bias figure for the tube, so that from this curve a complete picture of the orders of times involved can be obtained.

Input Impedance

In the conventional trigger tubes under discussion the discharge in the main gap is initiated by a certain current flowing in the trigger-cathode gap. In the general case the current has to be great enough so that the diffusion of the discharge products into the main gap reduces the main gap breakdown to the potential supplied to the anode or, in

Fig. 7. G1/370K triggering characteristic

CURVE	VALUE OF R IN MEGOHMS			
A	0.1			
B	0.5			
C	1.0			
D	2.0			
E	3.0			
	TRANSFER CURVES			
	V_a (volts)	R_c (k Ω)	C_c (μF)	
F	250	10	0	
G	260	10	0	
H	250	10	.001	
I	250	0	0	
J	275	10	0	



the case of the G1/370K, the discharge has, in fact, to be of sufficient magnitude for the cathode glow to come within the influence of the main gap.

From a circuit design point of view it is always desirable for the input impedance to the trigger electrode to be a maximum, and consequently a high series resistance is normally used. If the series resistance R_s is large enough to produce the conditions illustrated by the following equation a squegging or discontinuous discharge results;

$$V \text{ supply or pulse amplitude} < V \text{ maintain} + R_s I_{min} \quad .. \quad (4)$$

where R_s is the total series resistance,
and I_{min} is the minimum maintaining current which will maintain a discharge.

A typical current voltage characteristic is shown in Fig. 6(a). The normal glow region BC is that made use of in the well known stabilizer. An increase in current

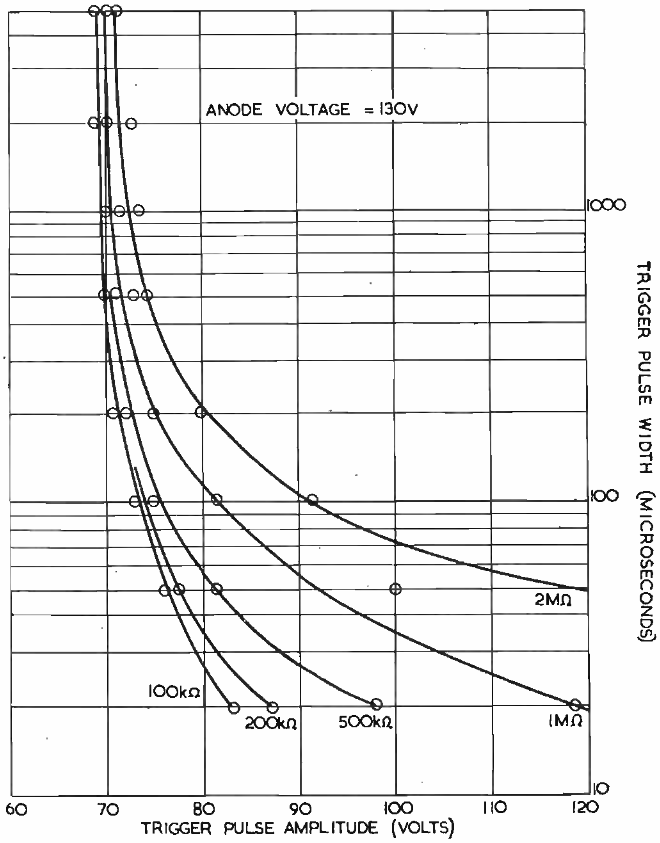


Fig. 8. G150/2D triggering characteristic

beyond this region brings about an increase in potential across the gap in what is termed the region of abnormal glow. In the section AB, the discharge characteristics change and the glow extinguishes itself at the point A at what has been defined as the minimum maintaining current. Fig. 6(b) represents a trigger-cathode gap of a trigger tube with a large resistance in the trigger circuit. The total resistance $R + R_K$ then gives R_s in Equation (4) and providing the condition defined therein is satisfied, a discontinuous discharge takes place. The waveform appearing at the anode is illustrated in (c) and the corresponding waveform developed across the cathode resistance R_K is shown in (d). After the first discharge the potential on the anode rises exponentially at a rate determined by R and C_s, the stray capacitance, until breakdown occurs at V_B. At this point the potential on the anode falls, due to the discharge which is insufficient to maintain itself, thus a sharp current pulse is produced across the cathode load and the anode potential again rises to V_B when another squeg pulse is generated. The interval between these pulses obviously depends upon the values of R and C_a.

This is the type of discharge which takes place when a triggering pulse is applied through a high series resistance. In category 1 tubes, it has been observed that transfer of the discharge to the main gap may occur as a result of the first or any subsequent squeg pulses, but in the G1/370K the transfer normally occurs on the leading edge of the first squeg.

When a square voltage pulse is applied to the series resistance the voltage actually appearing on the trigger electrode is deformed by the stray capacitances, so that the time lag between the leading edge of the triggering pulse and the appearance of the first squeg pulse is also dependent upon the value of the series resistance. It is possible, when using a short pulse, to increase the series impedance to such a value as to make this time lag greater than the applied pulse width, and under these conditions, of course, there is no discharge to produce a transfer to the main gap. Fig. 7 shows the formative delay, or time lag of the first squeg pulse after the leading edge of the pulse applied to the trigger electrode, as a function of pulse amplitude, as measured in the G1/370K. Five curves are given for different series resistances, and on the same curve the anode transfer characteristics are also plotted. Other curves showing the relationship of these particular parameters for the G150/2D are also shown in Fig. 8.

Noise

Before going on to discuss a number of circuits in which trigger tubes have been successfully employed, some mention should be made of the noise which can be generated in these tubes and which might, in some circumstances, render the application of this type of tube impracticable.

The noise normally associated with the trigger tube is generated when the glow moves its position on the surface of the cathode. This movement may be associated with a number of factors such as impurities of the cathode surface, stray fields due to insulator charges, etc. From this it is obviously desirable to operate the cathode at the limit of normal glow, in which condition the cathode surface is covered with glow and there can be no movement. However, it is not practicable to design a new tube for every application, and consequently each tube is generally applied over a wide range of current from the minimum maintaining current up to the limit of normal glow. It is therefore at the low current end where most noise is generated, and in general it is in this region of application that circuits are most sensitive to interference by stray pulses.

The normal current density at the cathode is determined by the choice of cathode material, electrode geometry, gases and their pressure. It has previously been shown that in order to reduce the deionization time to a minimum the anode cathode gap should be made as small as possible, which dictates the use of a high pressure filling. On the other hand, the input impedance to the trigger circuit is determined by the quantity of current required in this gap to cause transfer, and in order for this current to be small a low current density at the cathode, and consequently a low gas pressure, is required. In general then, a compromise solution has to be adopted, and the valve designer then has to take what steps he can to obtain a quiet tube, the most important of which is to obtain a clean tube, which is dependent upon the processing and pumping procedure. In addition to this, it is possible to take a further step to eliminate noise at low currents by producing small artificial barriers on the surface of the cathode which stabilize the position of the glow but do not interfere with the other properties of the tube.[7] The cathode of the G1/370K, illustrated in Fig. 2 is an example of this technique. Here the barriers are produced by indentations, and the diamond pattern which they produce are clearly visible in the illustration.

(To be continued)

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SCOTTISH TELEVISION

THE first regular programme transmissions from Kirk o'Shotts began on March 14 using the medium power vision and sound transmitters and the main mast and aerial system. This is an experimental service which will continue until the high power transmitters are completed later in the year.

The vision transmitter operates on a frequency of 56·75Mc/s (5·3 metres) and the sound transmitter on 53·25Mc/s (5·635 metres).

These medium power transmitters, which will ultimately be held in reserve in case of a breakdown of the high power transmitters, were built to B.B.C. specification by Marconi's Wireless Telegraph Company Limited. They form a completely separate installation and are housed in the Annexe Building.

The medium power vision transmitter is of the low level modulated type with a peak white output power of 5kW. Modulation is carried out at the 500-watt level and the signals are then amplified by two class "B" wide-band linear R.F. amplifiers each using a pair of English Electric Company type 5762 forced-air-cooled triodes. The appropriate shaping of vestigial side-band signals radiated by the vision transmitter is carried out in its own circuits, and not by a separate vestigial side-band filter as in the case of the high power transmitter.

The sound transmitter has an output power of 2kW and is of the conventional class "B" modulated type. As in the case of the vision transmitter, the crystal controlled drive and the power conversion equipment are built as an integral part of the transmitter.

The vision and sound outputs are combined in a Maxwell bridge diplexer type combining unit adjacent to the transmitters and the combined output fed into the main aerial transmission line system at a point close to the mast base.

The two transmitters are controlled and monitored from a desk which incorporates a built-in waveform monitor and two picture monitors in addition to the conventional controls and meters. The provision of the two picture monitors enables the incoming signals to be compared with those radiated. Programme switching for both sound and vision circuits is accomplished at this desk. Adjacent to the control desk are the vision and sound programme input equipment bays and the test waveform generating equipment which provides a variety of signals for testing, lining up and maintaining the characteristics and performance of the vision transmitter.

The vision programme is received at the station over the G.P.O. distribution network which consists of the 1-inch tube coaxial cable system from London to Birmingham, the ⅜-inch tube coaxial cable system between Birmingham and Manchester, and a radio-relay link between Manchester and Kirk o'Shotts.

The Post Office radio receiving terminal at Kirk o'Shotts is housed in a separate building on the B.B.C. site and the video frequency output from it is conveyed to the B.B.C. transmitting station by a short length of ⅜-inch coaxial tube.

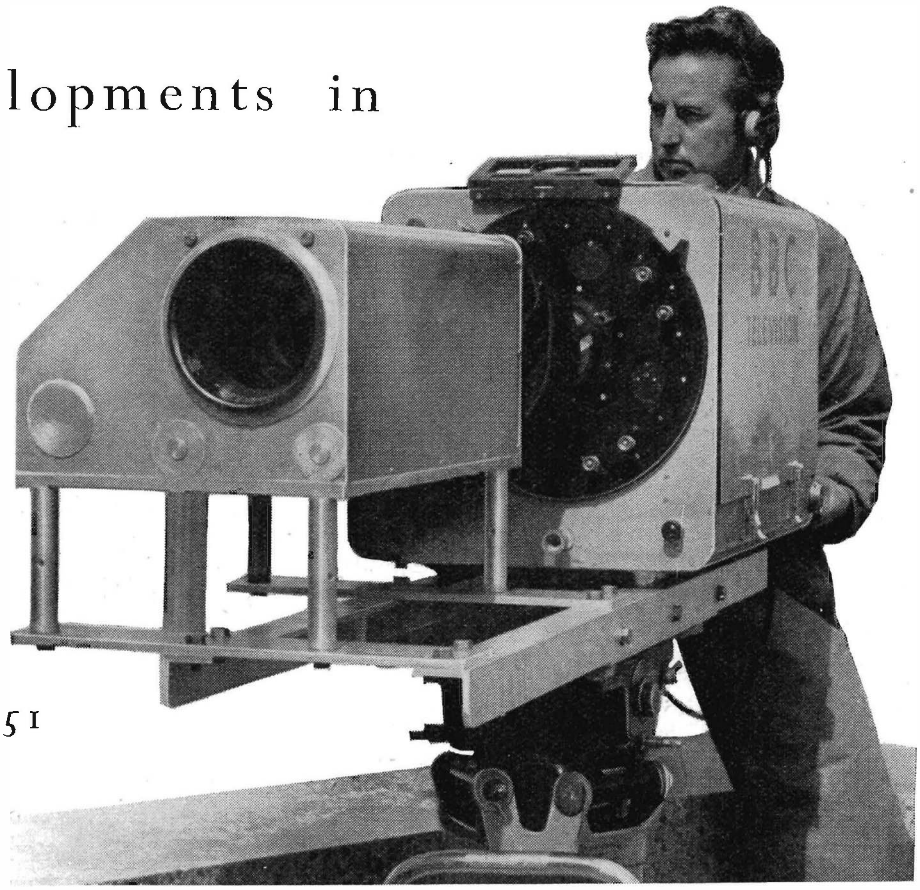
The sound programme reaches Kirk o'Shotts over specially equalized G.P.O. telephone circuits similar to those used for other B.B.C. transmitting stations.

Recent developments in

T V

OUTSIDE

BROADCASTING



A Review of 1951

by T. H. Bridgewater,* M.I.E.E.

1951, WITH its additional Festival stimulus, saw the fulfilment of several extensions and improvements to the B.B.C.'s Television Outside Broadcast (O.B.) service. The varied technical equipment associated with this organization has attained large and complex proportions and embodies many of the latest techniques known either in this country or elsewhere. Much has already been published on the post-war methods and equipment acquired and used by the B.B.C. for its expanding O.B. service, and the present intention is to review the main developments which came to fruition in 1951. One can conveniently consider this equipment under two main headings—namely, *Cameras* and *Transmission Links*—provided these are interpreted in the widest sense to mean, for the former, all the apparatus necessary for the picking-up in sound and vision of any chosen subject and its conversion into electrical form suitable for transmission (by cable or radio) and, for the latter, all apparatus used in the point-to-point transmission of such electrical waveforms generated by the cameras. Thus a new microphone or a special lens would fall under the first heading and an improved klystron or aerial under the second.

Cameras

The Pick-up Tube

The heart of any camera is, of course, its "pick-up" tube—if one may use this rather loose description for want of a better generic term for these electronic devices containing both light-conversion and scanning processes. Here the trend has been towards the greater use, latterly to the exclusion of all else, of the "Image Orthicon" type of tube—almost entirely on account of its high sensitivity and consequent ability to reproduce very sparsely lit scenes, some of which, for example, may reflect as little as 1ft lambert from high-lights. This tube, formerly made only in the U.S.A., is now manufactured and supplied by an English company. Although, just like its American counterpart, it has several inherent distortions or imperfections—such as an inability to cope with high light contrasts without introducing an artificial "halo" effect, less adequate resolution under low light, etc.—research is continuing apace and some amelioration is already evident; it remains to be seen how far this can continue.

Optics

Apart from the pick-up tube, the mechanical, optical and electrical design of the television camera as a whole reveals new features whose needs have been realized increasingly over the years. For example, on the optical side, a greatly improved "Zoom" lens has appeared. This device—a remarkable achievement on the part of the designers—enables the continuous variation of focal length up to a ratio of 5:1 which, if one visualizes the subjective effect of a 25:1 (approx.) change in the size of a scene, gives valuable flexibility to the cameraman and producer. This lens is so designed that, if first focused on a selected part of the scene (provided this is not nearer to the camera than 13 feet, which would seldom be the

* *British Broadcasting Corporation.*

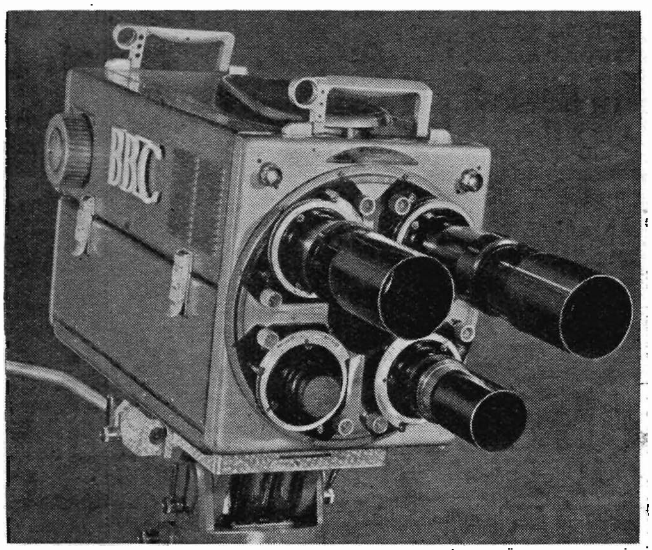
case with O.BS.) no adjustment of focus is needed during the "zooming" operation. The aperture is $f6{\cdot}3$.[1] Only one such lens has been available up to now but others will be coming into use. As will be seen from the illustration facing, the "Zoom" in its present form has considerable bulk, but this—although one hopes it may be lessened in the future—is more than outweighed by the valuable operational facility which it confers.

Another optical feature is the introduction of a subsidiary "turret" or disk carrying a selection of filters, any one of which can be rapidly swung into the space between the lens and the photo-cathode of the pick-up tube. These filters can be of various colours to correct for sky brightness or for the chromatic characteristics of the pick-up tube, as in photography, or they can be neutral to colour though attenuating the light by, say, 10 or 100 times. This latter facility is specially necessary with O.B.s where lighting levels at different events (or sometimes even at one location) may vary by ratios of many hundreds, and with most lenses such a degree of compensation is unattainable by adjustment of the iris diaphragm alone; there are, too, several objections to that method when control over a wide range is required. For the finer control of light, however, the iris is essential and is one of the best means of signal level adjustment in the camera channel; to use it effectively for this purpose involves remote operation from the control room and this long-wanted facility has now been introduced. Another and similar remote control is that for optical focus which can now be optionally taken over by the camera control operator on occasions when the cameraman may be too pre-occupied in framing and following some very fast-moving or other difficult subject.[2] These remote adjustments of iris and focus employ electro-mechanical principles, as also do other remote controls introduced for a less certain need, that is for horizontal "panning" and the rotation of the lens turret. On the supposition that there may be occasions when one could dispense with a cameraman, such as on scenes where little or no camera movement is required, it will now be possible to conduct some interesting experiments. (See Fig. 1).

Mobile Control Room

Attention has also been directed to the greater convenience and efficiency of the staff operating in the mobile control room. To this end the control units of both vision and sound equipment have been lightened in weight, simplified and streamlined in design, and constructed in such a way as to afford better access to components and

Fig. 1. The Pye image orthicon camera



valves—a difficult and not entirely soluble problem with the demands of compactness and technical efficiency always tending to conflict. As an indication of the present state of progress, so far as compactness is concerned, a complete camera channel giving a video output at standard level ready for transmission need only consist of the following main units: camera, waveform generator, camera control unit and power supply units, the total weight not exceeding 400lb. None of these units is larger than a suitcase.

A welcome amenity, although not one which may directly affect the pictures as seen by the viewer, has been the provision of cooled air inside the mobile control room. Hitherto the heat generated by the apparatus—up to 8kW—added to the normal air temperature produced almost unbearable conditions in warm weather and many staff have worked in temperatures exceeding 100°, often rising to 110°. Ordinary forced-air ventilation did little to alleviate the situation and in consequence a small refrigerating plant is now being built into the chassis, and it becomes easily possible to reduce the temperature to a comfortable level even in the hottest sun.

Microphones

On the sound side there have been further attacks on the, perhaps surprisingly, rather difficult problem of sound pick-up in conjunction with the television cameras, a problem besetting studios and O.B.s alike. Among the principal innovations have been lapel microphones and radio-linked microphones for commentators.[2] The former is an attempt to conceal the microphone when a commentator is speaking or interviewing—on aesthetic grounds as well as for convenience (the commentator otherwise usually has to hold the microphone)—and to restrain those being interviewed from the tendency to speak to and face the microphone rather than the camera. The microphone itself is of the miniature crystal type weighing a fraction of an ounce and easily worn in the button-hole, or attached in some other convenient position on the dress; a thin flex joins it to a pocket amplifier of the deaf-aid variety—very light and no larger than a packet of cigarettes—whence a signal of suitable level and at low impedance is conveyed by a trailing wire to the mobile control room along with all the other sound and vision inputs. The commentator's radio link—also, incidentally, employing a small crystal microphone—is essentially a method of freeing the commentator from the usual restriction of a trailing cable and equipping him instead with a radio transmitter for conveying his output to the mobile control room or some other convenient receiving point. This is especially useful at race-courses or at any other widespread event where the commentator may be required to rove at random, to cross streets or tracks and, although often still remaining in view of a camera (the latter keeping him in "close-up"; perhaps with a telephoto lens), generally to move with a freedom which would be quite impossible if he had to be joined to and followed by the usual cable. The transmitter—with an output power of one watt, frequency-modulated on a carrier frequency of approximately 90Mc/s—has been made as compact as possible without too far sacrificing speech quality, and is harnessed to the commentator's back, its short telescopic rod aerial extending vertically above. So that the commentator may be kept in touch with the rest of the programme and receive cues and instructions he can also "wear" a small receiver, with the output fed into headphones, which picks up from a "base" transmitter (usually located at the receiving point referred to above); this channel is amplitude modulated and employs a frequency also near 90Mc/s. Under favourable circumstances the range of this "radio-microphone" can exceed one mile, but the usual requirement in television—where normally the commentator would keep within camera range—is for shorter distances, say, up to a quarter of a mile.

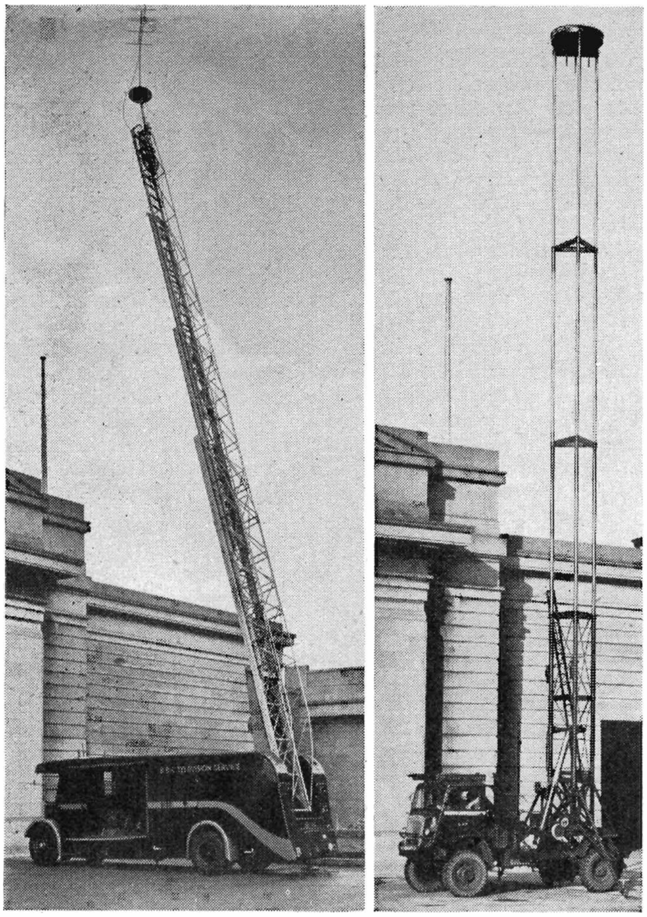


Fig. 3. (Left) Combined aerial, transmitter and power vehicle, (right) telescopic tower for T.V. outside broadcasts

Transmission Links

EXTENSION OF RANGE

The essence of an O.B. is its detachment or remoteness, and often its newness; hence there may well be a different transmission problem with each programme. Solutions are many, varied and often intricate.[3] We have probably reached the stage where, in the judgment of the viewing public, significant progress in Outside Broadcasting will be measured, not so much by further improvements to technical quality, but by the extent to which topical events in any part of the country and, ultimately, in any part of the world, can be televised and seen in all homes. In other words the further development of radio and cable transmission links must, as is acknowledged by the B.B.C., play an increasingly vital part in improving the service.

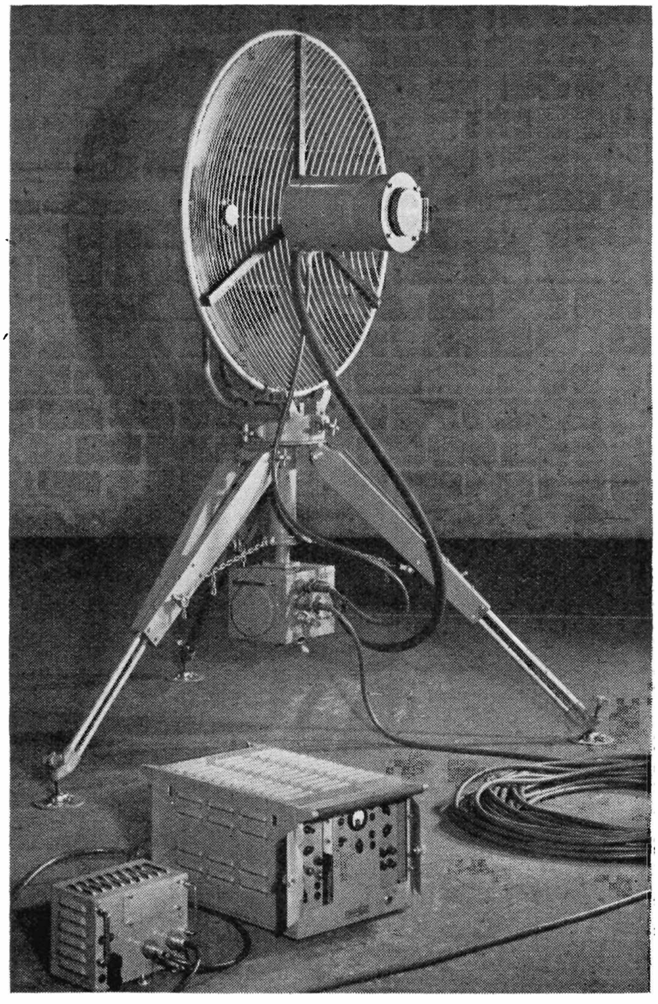
V.H.F.

The present emphasis[3] is largely on centimetric-wave "multi-hop" technique, and equipments operating in the region of 4,500Mc/s and of 6,800Mc/s have been brought into use during 1951. These are not yet, however, entirely displacing other wavebands—nor is it expected that they will: indeed active experiments are continuing in the V.H.F. range, including, for example, the region of 190Mc/s. Frequencies close to this have been used for low power (about 15 watts) portable equipment on several occasions[4,5] and there are also applications for a longer-range transmitter (about 350 watts) on the same frequency; this latter does not so rigidly demand the unobstructed visual transmission path needed for the higher frequencies and it is therefore advantageous to have available an alternative of this kind for circuits whose signal paths are not as clear as they should be—or for circumstances where a relatively wide beam is essential (such as with a moving transmitter). One 350 watt transmitter has been acquired during the year under review and is installed in the cabin of a vehicle carrying one of the fire escape types of extensible mast, the latter supporting an aerial consisting of a folded dipole with one reflector and two directors; the power supply is also on board—a single-phase 15kW alternator driven from the road engine—so that the single vehicle carries an entirely self-contained mobile transmitting station. (See Fig. 3.)

S.H.F.

In the centimetric-wave field two main types of transmitter have been taken into service. One type, which operates in the 6,800Mc/s region, embodies a low-power klystron, giving an R.F. output of 100 milliwatts, this being frequency-modulated by applying the video signals to the repeller electrode. No aerial of conventional form is used but the short waveguide which leads out the carrier is flared at the end and from a point near the focus directs its energy on to a metal parabola of 4ft diameter; the latter reflects and transmits the wave in a narrow beam, the angle of divergence being less than 3°, equivalent to an aerial gain of 37db. The corresponding receiver uses a similar aerial system and klystron, though in this case the oscillations are made to beat with the incoming carrier to yield an intermediate frequency of 117Mc/s.

Fig. 4. Centimetric-wave radio link equipment



The other type of centimetric-wave transmitter operates in the 4,500Mc/s band and although the main principles are similar there are some interesting variations. The klystron is a new high-power type yielding an output of aproximately 5 watts: this entails air cooling and a fan is provided for the purpose. The I.F. of the receiver is 90Mc/s. The aerial reflector is again a 4ft parabola but is constructed of parallel tubes of light alloy, the tubes air-spaced from one another to give an openwork or basket appearance. Apart from a reduction in weight this construction results in an appreciable lessening of wind resistance at the cost of only a negligible loss of reflecting efficiency (Fig. 4). Another feature associated with this equipment is a superimposed sound channel achieved by the use of a sub-carrier, making it possible to transmit the sound and vision together; this might well prove a useful facility for occasions where land-lines for sound are unavailable. The lower frequency used by this equipment yields a rather wider beam but this is more than offset by the extra power and ranges up to 50 miles have been achieved.

Mobile Masts

The problem of elevating a radio link aerial is one which has hitherto been solved mainly by the use of extending ladders built on the fire-escape principle. These are immensely useful for V.H.F. purposes and attempts have also been made to adapt them to support the reflectors used for centimetric-wave transmissions, but one of the problems with these is the need of very high stability in the face of strong winds. It is thought that this may be better achieved by the use of some form of telescopic tower, and during the year one such has been acquired: this consists of a platform (large enough to support the transmitter and reflector) mounted on three telescopic legs, the latter capable of extending under hydraulic pressure to 80 feet, the whole being mounted on a road-vehicle chassis to give normal mobility. (Fig. 3.)

Cable Links

On the cable side of transmission links the Post Office has contributed notable extensions. In particular the installation of 2-way coaxial cables between London, Birmingham and Manchester has opened a vast new field for O.B. programmes, especially when later extended by the facility to tap this cable at intermediate repeater points, as has indeed already been done experimentally at Coventry.[6,7]

General

Additions to Equipment

Apart from attention to quality by various improvements such as those discussed in the foregoing paragraphs, the Corporation has, during the year under review, made extensive additions to its total stocks of equipment for outside broadcasts. For example, the number of mobile control rooms (each of these consisting of three cameras and associated control units, amplifiers, and power supplies, microphones and their amplifiers, mixers, etc., complete with vehicles and all auxiliaries necessary for an entire installation and production—except for the transmission link itself) has been increased from three to six; four more mobile telescopic aerial masts of various kinds have been acquired; likewise some half-dozen centimetric-wave links with sundry vehicles and much ancillary equipment. Much more is projected.

Future Plans

With these enlarged resources the B.B.C. has begun to implement plans for the wider gathering of outside events. During the past summer the cameras travelled as far as Glyndebourne on the south coast (with a 3-stage centimetric-wave circuit to London) and Nottingham in the other direction. Since then they have gone further north—to Blackpool, Manchester and Leeds. This year they should reach Scotland, South Wales and the West Country. To cover such a wide field speedily and efficiently the B.B.C. is now setting up regional bases, firstly in the Birmingham area, then later this year in Scotland (Glasgow/Edinburgh area) and South Wales. Each region would be equipped basically with one mobile control room and two radio links, leaving in London three or four mobile control rooms and some half-dozen links. These latter would serve the needs of programmes in the south and also provide a pool from which Regional Units would draw when on occasion requiring to extend their local facilities.

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BARNSTAPLE TRANSMITTING STATION

In accordance with the previously announced plan to improve reception of the Home Service Programmes in certain areas, the BBC is building a new low-power transmitting station at Fremington between Barnstaple and Bideford, Devon. As, however, the building and installation will take some considerable time to complete a temporary transmitter installed in a caravan will be used on the site in order that listeners in this area may have an improved service earlier than would otherwise have been possible.

The caravan transmitter will be brought into service on March 9, 1952, with a wavelength of 285m (1052kc/s) and will radiate the West of England Home Service. The aerial system already erected for the permanent station will be used for the temporary transmitter.

The temporary transmitting equipment consists of two 250-watt transmitters, one normally being a reserve for use in the event of a breakdown, but provision is being made for paralleling the two outputs to give a total aerial power of 500 watts.

The programme will be fed to the transmitter over Post Office circuits. Four G.P.O. lines are terminated in the vehicle: a programme line and a spare programme line, a control line to the nearest BBC centre and a G.P.O. telephone circuit.

Power for the transmitter is obtained from the British Electricity Authority, who have terminated their supply cable on the site in a small kiosk which houses the main fuses, metering equipment and main switch, and is provided with an outlet socket to take a special heavy-duty watertight plug to which is connected the main cable feeding the caravan.

A standard four-berth caravan, measuring approximately 7ft wide and 20ft long, mounted on a specially strengthened chassis and with its interior arrangement modified to BBC design, has been used. The vehicle is electrically heated, the distribution fan of the system being capable of independent operation for cold air circulation, if required in the summer. Additional extract fans are provided to discharge waste heat from the transmitters through louvres in the side of the vehicle in hot weather. Space has been left for the future installation of remote control gear which would enable the transmitter to work unattended. It would then be remotely operated over a Post Office telephone circuit from the nearest permanent BBC establishment.

An Electrical Flowmeter
for Recording Blood Flow

By I. G. Baxter,* B.Sc., A.R.C.S.

THE flowmeter to be described was designed for continuously recording the rate of flow of blood to the lungs of an animal, in connexion with research on respiration. The instrument embodies a differential capacitance manometer that registers the pressure output from a miniature pitot head, which is built into a special cannula that can be inserted into the pulmonary artery. Details of this cannula and the more physical aspects of the system have been published elsewhere.[1]

General Principles of the System

The instrument is shown schematically in Fig. 1. An R.F. oscillator is loosely coupled to an LC circuit which

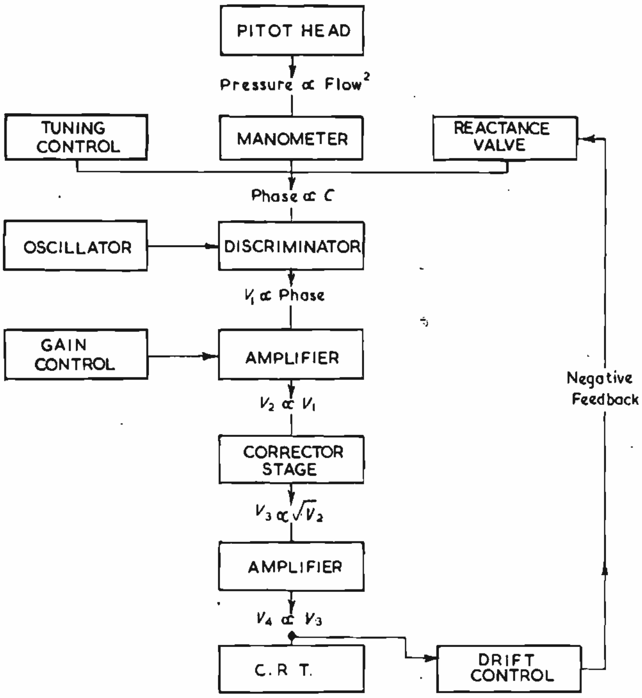

Fig. 1. Schematic diagram for flowmeter

includes the manometer. A discriminator valve detects the phase relationship between the oscillator potential and that across the driven LC circuit, and produces an output signal which is fed through an amplifier and a correcting stage to a cathode-ray tube. The correcting stage renders the trace deflexion linear with rate of flow, by compensating for the square-law relating pressure output to flow, which characterizes the pitot head. Drift is eliminated by a form of negative feedback.

The complete circuit diagram is shown in Fig. 2, and the working of the arrangement will now be described more fully, section by section.

Manometer

The manometer comprises a plane circular electrode mounted very close to a diaphragm 0·5in. in diameter, across which the differential pressure from the pitot head is applied through narrow connecting tubes. The mass loading of the liquid in these tubes necessitates a stiff diaphragm, to make the natural frequency of the manometer high enough to respond to rapid flow changes; the frequency is about 150c/s, which is well above the highest frequency component of the flow waveform associated with a typical heart rate of 3 beats/sec.

The rigid diaphragm means that, even with an electrode gap of 0·001in., the pressure sensitivity is only $2{\cdot}5 \times 10^{-3}$pF/mm/Hg. As the peak pressure output from the pitot head is 15mm Hg (corresponding to a flow of 30cc/s), the capacitance changes to be measured are of the order 0·04pF and less, or about 0·02 per cent of the 200pF comprised by the manometer, its connecting cable, and residual capacitances. A fairly sensitive method of measurement is therefore entailed; this led to the choice of a phase modulation system.

Phase Discriminator

Use is made of the rapid change of phase angle, ϕ, between current and potential that occurs when the tuning of a low loss LC circuit is varied in the region of its resonance with an A.C. driving source (Fig. 3). The phase angle, θ, between the potentials v_1 and v_2 also varies steeply with C when $LC \approx 1/\omega_0^2$. For example, if $C = 200$pF and Q = 100, $d\theta/dC \approx 30°$/pF at resonance.

A stable oscillator circuit described by Gouriet[2] is used for generating the carrier A.C., at a frequency of 500kc/s. The potentials v_1 and v_2 are applied to the suppressor and control grids of a pentode employed as the phase discriminator. Grid current provides automatic g_1 bias, but bias has to be provided otherwise for g_3, because at the instants when current is flowing this electrode is not necessarily positive and able to collect a charge; without proper provision of bias, very peculiar behaviour can occur. By suitable adjustment of the suppressor bias potential, the discriminator output can be made independent of minor variations of oscillator output amplitude.

The anode current is doubly gated by the two grid potentials, which are of sufficient amplitude to cut off on negative half cycles. The mean current therefore depends on the phase of v_1 relative to v_2, varying from a maximum when $\theta = 0$, to zero when $\theta = \pi$. The anode load of the discriminator is a damped LC circuit tuned to the carrier frequency, and the alternating output potential at the anode is rectified by a diode to produce a steady potential for feeding through an R.F. filter network to the succeeding amplifier valve. The diode is biased by a potentiometer tapping such that the input to the amplifier is selected from the linear part of the discriminator output curve, (Fig. 4). The gain of the amplifier is controlled by a stepped cathode resistor; an alternative negative feedback method of wider range which has been used successfully, is to bias the diode by any desired fraction of the amplifier output, obtained by a potentiometer network from the anode.

Correcting Stage

The input potential to the correcting stage is proportional to the square of the rate of blood flow, and the stage is therefore required to produce an output propor-

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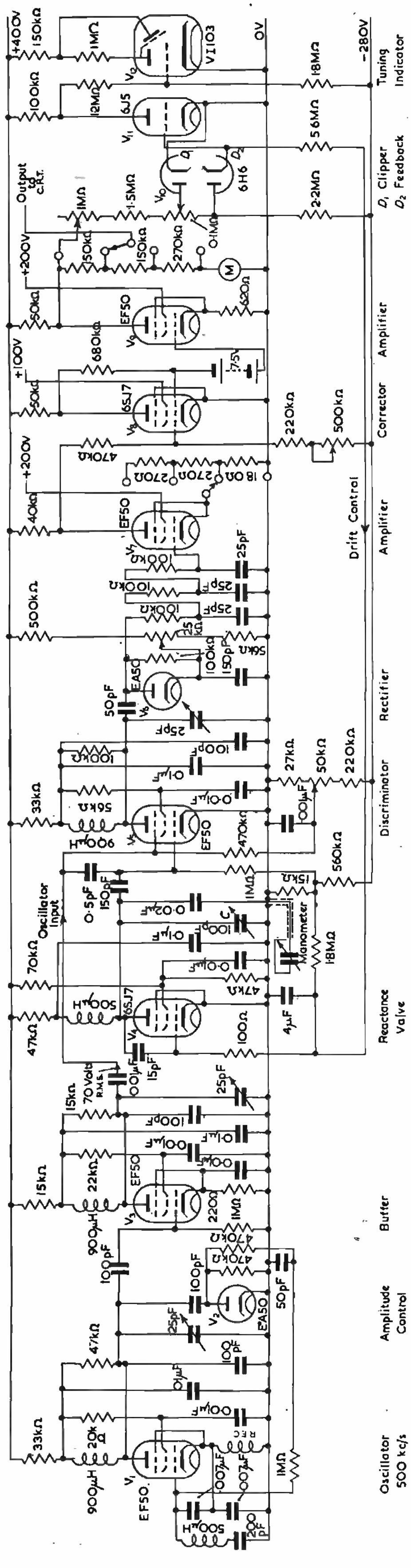


Fig. 2. Complete circuit diagram

tional to the square root of its input, so that the overall calibration of the instrument may be linear. As extreme accuracy is not required, advantage is taken of the approximately parabolic i_a/v_g relationship, that corresponds to the nearly linear g_m/v_g behaviour, exhibited over a wide range of its characteristics by a 6SJ7 pentode valve. The latter is used in a modified See-Saw[3] fashion; analysis (see appendix) shows that, measuring from a suitable origin, changes in grid potential are proportional to the square root of the input potential. The excursion of grid potential is too small and the output impedance is too high for direct use, so a further stage of D.C. amplification precedes the C.R.T. display unit. Fig. 5 depicts the measured overall performance of the correcting stage.

Drift Control

The bogus changes in output level caused by L.F. noise or drift are rendered more than normally undesirable by the fact that the corrector stage will cause severe distortion if its input potential corresponding to zero flow is incorrect. As the peak sensitivity of the circuit is 6·5kV/pF (corrector stage input), it is clearly impracticable to eliminate drift by ordinary care in design; the need for repeated manual resetting is accordingly avoided by providing an automatic drift control or D.C. restoring circuit. In effect

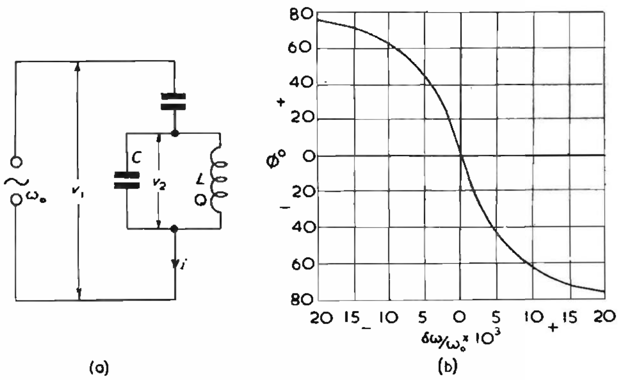


Fig. 3. (a) Elements of phase modulation system. The relative phase of v_1 (or i) and v_2 changes rapidly with variations of C, near resonance.

(b) Calculated relationship between ϕ (phase of v_2 relative to i) and $\delta\omega$ (difference between ω_0—frequency of source—and that of driven LC circuit at resonance)

this is a negative feedback loop which scrutinizes the output potential corresponding to those half cycles when there is no flow, and if this deviates from its predetermined value for an appreciable time the grid bias of a capacitance valve is altered to re-tune the manometer LC circuit. This scheme can only function with an intermittent flow such as that in the arteries from the heart close to their origin.

Referring to Fig. 2, the capacitor C is adjusted so that with zero flow the output potential tends to exceed its correct starting level (Fig. 5). As soon as this occurs, the diode D_2 conducts, raising the potential of the control grid of V_4 from its normal level and altering its equivalent capacitance in a direction tending to oppose the incorrect setting. In this way the output potential is stabilized at its proper level. If the output now fluctuates due to the manometer responding to a pulsating flow, the automatic control will continue acting to set the upper limit of the output waveform at the same level. To prevent the feedback trying to eliminate the waveform it is desired to record, the control grid of V_4 is connected to an RC network which gives the drift control a time-constant long compared with the duration of a heart beat. A clipping diode D_1 is included to avoid unnecessarily fierce drift con-

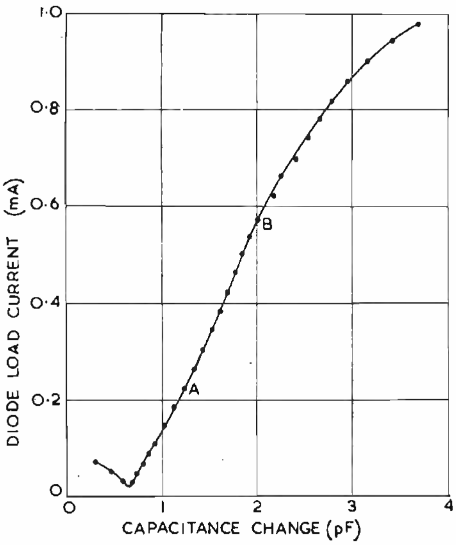


Fig. 4. Measured characteristics of discriminator stage, with 100kΩ diode load. The curve is almost linear between points A and B

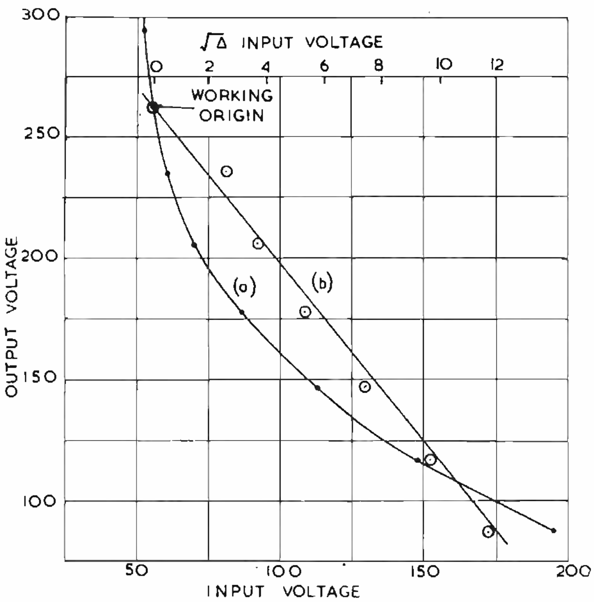
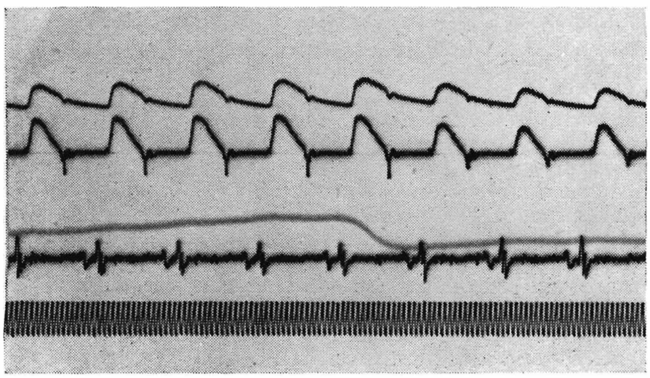


Fig. 5. Measured characteristics of correcting stage. The output voltages are plotted against the input voltages at (a), and against the square root of input voltage changes at (b). A straight line has been fitted to points (b) for comparison

Fig. 6. Record obtained from a cat. Reading downwards, the traces are: pulmonary arterial pressure, pulmonary arterial flow, intrapleural pressure, electro-cardiogram, 50c/s time marker



trol being caused by brief large excesses of output potential.

Under steady conditions the required approximate setting of C is carried out by reference to the voltmeter M. The meter response is too slow for use when the output is fluctuating, however, so an additional magic-eye tuning indicator is fitted. This is operated through an amplifier valve V_{11} from the cathode of D_2; the eye flickers when C is correctly adjusted and feedback signals are being transmitted.

Performance

The instrument registers rate of flow, so that the recorded waveforms have to be integrated to obtain total volumes. This could readily be performed electrically, but it has been carried out so far with a "hatchet" planimeter run over the photographic record of flow rate.

The approximate calibration of the equipment was determined by combining the individual calibrations of the component sections, starting with the pitot head and ending with the camera magnification. To lessen the consequent possible build-up of errors, the result was checked by applying step changes of pressure to the manometer while recording the C.R.T. spot deflexion. Finally, the overall calibration figure obtained in this way was used in a pulsating flow test; a cam operated piston valve was used to interrupt the flow from a pressurized tank which had the pitot cannula fitted in its outlet, and the outflow was collected during timed intervals and measured. The discrepancy between the directly measured value of flow rate and that given by the flowmeter averaged 4 per cent regardless of sign, over a range of different rates of flow with two arbitrary waveforms.

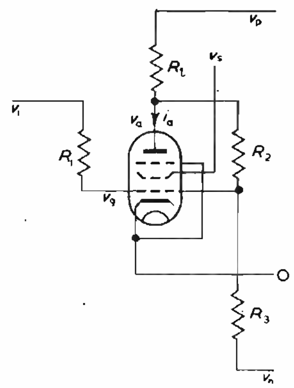


Fig. 7. Elements of corrector stage

An example of the flow record obtained in a typical physiological experiment is given in Fig. 6.

The author is grateful to the Editors of the Journal of Physiology for permission to publish this article.

Appendix

Theory of Corrector Stage

In Fig. 7, a variable-mu valve with anode load R_l is connected in a resistor network R_1, R_2, R_3, into which is fed an input potential v_1.

If the relationship of anode current to grid potential may be regarded as parabolic, then

$$i_a \approx \alpha\,(v_g - v_g')^2 + (v_a - v_a')/\rho \quad \dots\dots\dots\dots (1)$$

where v_g' is the grid potential at cut-off and v_a' the corresponding anode potential. ρ and α are valve parameters.

The excursion of grid potential is small enough to be disregarded, so that the equivalent resistance of the resistor network, looked into at the anode, can be taken as $R_1R_2/(R_1 + R_2)$. Therefore

$$v_a - v_a' = -i_a R_l R_2/(R_l + R_a) \quad \dots\dots\dots\dots (2)$$

Substituting (2) in (1), and writing

$$\alpha_1 = \alpha / \left\{1 + R_l R_2/(R_l + R_2)\rho\right\}$$

gives

$$i_a = \alpha_1 (v_g - v_g')^2 \quad \dots\dots\dots\dots (3)$$

Two further relationships may be derived by inspection:

$$v_g = v_n + R_3\left\{(v_1 - v_g)/R_1 + (v_a - v_g)/R_2\right\} \quad \dots\dots\dots\dots (4)$$

and

$$v_a = v_p - R_l\left\{i_a + (v_a - v_g)/R_2\right\} \dots\dots (5)$$

Rearranging (4) gives

$$v_a = R_2/R_3[v_g\{1 + R_3(1/R_1 + 1/R_2)\} - v_n - v_1R_3/R_1] \quad .. \ (6)$$

Rearranging (5) and substituting for i_a from (3), we obtain

$$v_a(1 + R_l/R_2) = v_p - R_l[\alpha_1(v_g - v_g')^2 - v_g/R_2] \quad .. \ (7)$$

Substituting in (7) for v_a from (6), and rearranging,

$$\alpha_1R_l(v_g - v_g')^2 + v_g\{1 + (R_2 + R_l)(1/R_1 + 1/R_3)\}$$
$$= v_1(R_2 + R_l)/R_1 + v_p + v_n(R_2 + R_l)/R_3 \quad .... \ (8)$$

which may be written

$$Av_g^2 + Bv_g + Cv_1 + D = 0 \quad .... \ (8a)$$

If v_1 is proportional to the square of some quantity x, or

$$v_1 = kx^2 + l \quad .... \ (9)$$

then by giving the various circuit constants suitable values and choosing an appropriate origin, it is possible to establish a simple relationship

$$v = Mx$$

where $v = v_g + m$ .... (10)

Thus, substituting in (8a) for v_1 and v_g from (9) and (10),

$$Av^2 + v(B - 2Am) + Am^2 - Bm + Cl + D + Ckx^2 = 0$$

Therefore if $B = 2Am$ and $Cl + D = B^2/4A$, then $v^2 = -Ckx^2/A$, and the desired linear relationship between the output potential and the input variable is achieved.

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A High Speed Crystal Clutch

By M. Lorant

AN experimental crystal clutch recently developed at the U.S. National Bureau of Standards is believed to be the first of its type. In the new clutch, application of a D.C. voltage to the electrodes of three "Bimorph" piezo-electric crystal elements causes bending of the elements; this bending presses the clutch output disk against the rotating input disk. The new experimental unit was devised as part of a programme for the development of fast-acting clutches for use in high-speed computors.

Distinguishing features of the crystal clutch are high speed of response and almost negligible current drain. No current flows, other than insulation leakage, after the applied voltage has charged the capacitance of the crystals.

In the only model thus far constructed, the output shaft delivered useful torque in as little as 0·2 millisecond after voltage was applied. Output torque of the engaged clutch was approximately 16·5 ounce-inches at 400 volts excitation, or 21 ounce-inches for 500 volts. The no-voltage drag torque, however, was about 7·5 ounce-inches, a substantial fraction of the engaged torque.

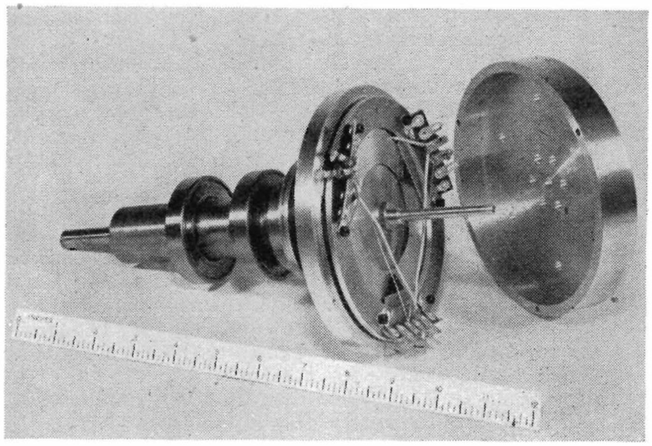
Construction of the crystal clutch is essentially simple. The output disk is located between two rotating members: a thin, flexible crystal pressure plate and a heavier mounting plate or input disk. Three of the Bimorph crystal elements, which bend when opposite potentials are applied to different parts of the crystal surface, are spaced at 120-degree intervals. When the exciting voltage is applied, the crystals press against the pressure plate and the input disk.

The clutch proper and its immediate mounting occupy a space about six inches in diameter and a little more than an inch long. The complete assembly includes, in addition, internal bearings for the output shaft, bearings and mounts for the entire assembly, a drive pulley, and slip rings for transmitting the exciting voltage to the rotating assembly.

Several factors enter into the design of a clutch of this type. Speed of response is related to the inertia and loading of the output system, the available torque, the distance the crystal pressure point must move before it begins to pinch the output disk, and the resonant frequency of the crystal itself. It is the resonant frequency that sets the ultimate limit for speed of response.

The dimensions of the Bimorph crystal determine not only its resonant frequency but also its sensitivity. Since increased crystal thickness is favourable to high resonant frequency but unfavourable to high sensitivity, design dimensions must be matters of compromise and judgment.

If resistance is present in the excitation circuit, the voltage appearing across the crystals will rise exponentially while the crystal capacitance (about 0·0065μF) is charged. If the voltage rise is excessively slow, speed of response will, of course, be impaired. It might be thought that if resistance were eliminated, so as to give very fast voltage rise, speed of response would be a maximum. This does not prove to be the case, however. Instead, an irregular output motion appears, probably due to bouncing of the crystal against the output disk, while response time shows no significant improvement.



The experimental crystal clutch, unmounted and with the cover plate removed.

Obviously, the crystal clutch does not have wide applicability. Yet its high speed and negligible current drain could be very valuable in a few highly specialized but nevertheless important instrumentation functions. In special photographic recording apparatus, for instance, the crystal clutch could be used to move motion picture film in fast response to an actuating voltage. The experimental clutch model could undoubtedly be improved upon; in fact, several desirable modifications have already become apparent.

Dot-Interlaced Television

By G. G. Gouriet,* A.M.I.E.E.

ALL readers with a technical interest in television will be familiar with the principle of line-interlacing, and most will have heard of the more recent development known as dot-interlacing, which is now creating widespread interest,[1,2] particularly in its application to colour television. Both these terms describe artifices which may be introduced into a television system for the purpose of obtaining what may be termed a "subjective" increase in the maximum amount of information which may be transmitted in a given bandwidth. At the outset it must be emphasized that for a given bandwidth, the amount of information which can be transmitted, by conventional methods, *in a given time*,† that is, the *rate* of sending information, cannot exceed a fixed maximum, a fact which was revealed by Hartley in 1927, and has become known as Hartley's Law.[3] The most that we can, therefore, hope to accomplish by means of such artifices as we are discussing here is a subjective improvement, and this may be achieved only by exploiting the deficiencies of our senses. Thus, in simple line interlacing we exploit the fact that, in general, the frame repetition rate which is required to provide the illusion of continuous motion is less than that which is required in order to avoid flicker. In the present day British system of television, frames each containing only half the total picture information are presented at the rate of 50 per second, so that a complete picture which comprises two frames is presented at the rate of 25 pictures per second. Since a picture repetition rate of 25 pictures per second is more than adequate to create the impression of continuous motion (except for very fast-moving objects) it might be argued that the process could be extended, and while still maintaining the rate of 50 frames per second in order to avoid brightness flicker, still less information might be transmitted in each frame so that a still longer period would be taken to complete a picture. In order to distribute equally the information contained in each frame, a logical development, following the double interlacing of the horizontal scanning lines, would be to divide the picture into vertical lines and to transmit the information contained in alternate vertical lines on successive frames. It is interesting to note that this result might be achieved by alternately scanning successive frames horizontally, and then vertically, so that with simple interlaced scanning four frames would be required to complete a picture. However, nothing would be gained by this procedure, since at the points where the horizontal and vertical scanning lines intersected, picture information would be scanned twice during two successive frames, and the extra time taken to complete a picture would thus be accounted for by this unnecessary repetition.

In fact, if a raster composed of horizontal scanning lines is further divided into the appropriate number of vertical lines, each line will become broken up into dots, and each dot will represent a picture element. The problem, then, is to find a means of breaking up the picture signal, which is normally continuous along each line, into a series of short-duration signals or "samples", and a further degree of interlacing will then be obtained by transmitting alternate samples on successive frames.

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† *In fact modern information theory has disclosed that by adopting coding methods, bandwidth may be exchanged for signal/noise ratio.*

The Theory of Sampling

It is well known that all the information contained in a signal, the spectrum of which extends up to a frequency, f_c, may be transmitted by sampling the signal at regular intervals provided that the sampling frequency is not less than $2f_c$. Sampling is achieved simply by causing the signal waveform to modulate the amplitude of a train of pulses, and the process, which is more formally known as pulse amplitude modulation or P.A.M., is illustrated in Fig. 1, in which the broken line indicates the modulation waveform.

The simplest explanation of the fact that $2f_c$ pulses per second are required to convey information containing a maximum frequency, f_c, is that a minimum of two pulses, one "long" and one "short", are required to describe one cycle of a sine wave. This simple explanation is, of course, very loose, and the rigorous answer is to be found by examining the spectrum of the modulated pulse train. The spectrum of a train of pulses, the duration of which is short compared with the repetition rate, is well known to comprise a constant or D.C. term, a fundamental component which is the pulse repetition frequency (P.R.F.), together with a large number of harmonics. Over the frequency range in which we shall be interested, all components (with the exception of the D.C. term) are of substantially equal amplitude, and such a spectrum is shown in Fig. 2(a). Since the actual amplitude of the spectral components is proportional to the amplitude of the pulse train, it follows that in the case of a modulated train each component will be modulated. Modulated D.C. is simply the modulation signal itself, while for the remaining components, modulation will result in the generation of symmetrical sidebands about each of them. In Fig. 2(b) the spectrum is shown for a modulating signal containing frequencies up to half the P.R.F., and it is evident that modulation at any higher frequency than this limit would cause the sidebands to overlap, with the consequent introduction of spurious frequencies into the modulating spectrum. It will be noted from Fig. 2(b) that the original modulating signal may be recovered from the modulated pulse train by passing the latter through a low-pass filter with a cut-off frequency equal to half the P.R.F. At this point the question might well be asked, what is the value of the sampling method for communication in purposes in general? The answer is that for the purpose of a single channel it is normally of no value at all. The bandwidth required to transmit the samples is many times greater than the highest permissible modulating frequency. However, for the price of bandwidth, sampling offers an economy in time, and the interval between pulses may be utilized by allowing other transmissions to share a single circuit on a time sharing basis.

For television transmission, a straightforward sampling as described above would not be a practicable proposition. Firstly, we could not afford to send two samples to describe one cycle of a sine wave; it would be cheaper in bandwidth to send the sine wave itself. Secondly, the samples could not be transmitted as pulses, again because the bandwidth required would be prohibitive. To take the first objection, let us examine the result of sending only one pulse per cycle of the highest modulating frequency. In other words, what happens if we modulate a pulse train with a signal having a spectrum which extends up to the P.R.F. The spectrum of the resulting signal will be as shown in Fig. 3, that is, the side-bands will overlap completely. Apart from the fact that there is a conglomeration of misrelated information, this does not present a very clear picture of the result. A much clearer picture is obtained by forgetting the spectrum and reverting to the time-function. Consider the simple case in which a sine wave is sampled at a rate only slightly greater than its frequency. The result is shown in Fig. 4(a), and by comparison with Fig. 4(b) it will be seen that there is complete ambiguity as to whether it is the sine wave in question or a different wave of considerably lower frequency which is being sampled. The low frequency is, of course, the difference between the sampling rate and the frequency of the sine wave. If we compare this result with that obtained when the same signal is sampled by a pulse train displaced in time by half the pulse interval as in Fig. 4(c), we see that the difference frequency is displaced by 180° and will, therefore, be cancelled if the signals of Figs. 4(a) and 4(c) are added. By adding the signals of Figs. 4(a) and 4(c) we have, of

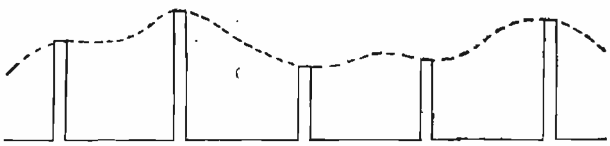

Fig. 1. Modulated pulse train

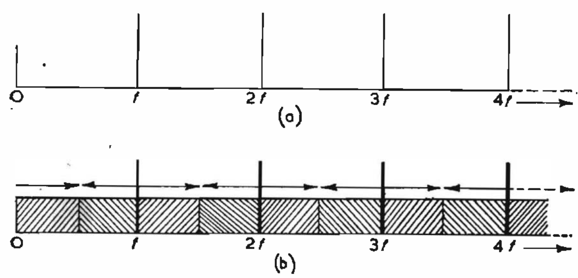

Fig. 2. (a) Unmodulated pulse spectrum. (b) Modulated pulse spectrum

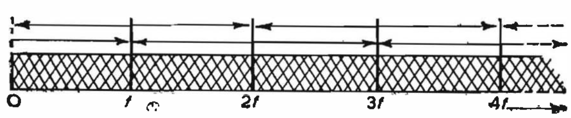

Fig. 3. Overlapping sidebands due to modulating up to frequency f

course, in effect doubled the rate of sampling, and it has previously been shown that twice the rate was sufficient to avoid distortion. In fact, this is simply another way of stating the previous argument, but a rather useful way, since it explains an important principle of dot interlacing—in fact interlacing in general. Sampling at a rate less than twice the highest frequency present in the signal waveform will introduce spurious information, but if the sampled signal is recorded or temporarily stored, further samples may be added to the stored signal at a later time and the result will be the same as if the sampling rate had been doubled, and the spurious information will be cancelled. Considering the case of a stationary television picture, samples taken along each line at half the required rate may be presented on one frame while further samples taken at intermediate points are presented on the succeeding frame. With complete addition, the effect will be the same as if the sampling rate had been doubled, but in fact twice the time will have been spent in completing the construction of the picture. It should be noted here that the storage necessary for the addition of the two sets of samples may take place in the human eye by virtue of persistence of vision, but more will be said of this later. Also, we shall discuss later the question of movement, but for the present a stationary picture will be assumed.

The first point, then, is that we may limit the sampling rate to one sample per cycle of the highest frequency which we wish to transmit, only provided that we are prepared to allow more time to complete a picture.

The next point concerns the transmission of the samples, which, as we said earlier, cannot be sent as pulses because of the prohibitive bandwidth which would be required. As a first thought it might seem reasonable to limit the bandwidth so that the repetition rate of the samples is transmitted but no harmonics. Reference to Fig. 3 shows that in these circumstances the spectrum of the samples would then comprise the original modulating signal plus a "scrambled" version in which the high frequency components appear as low frequencies and vice versa. Without stopping to consider whether or not an

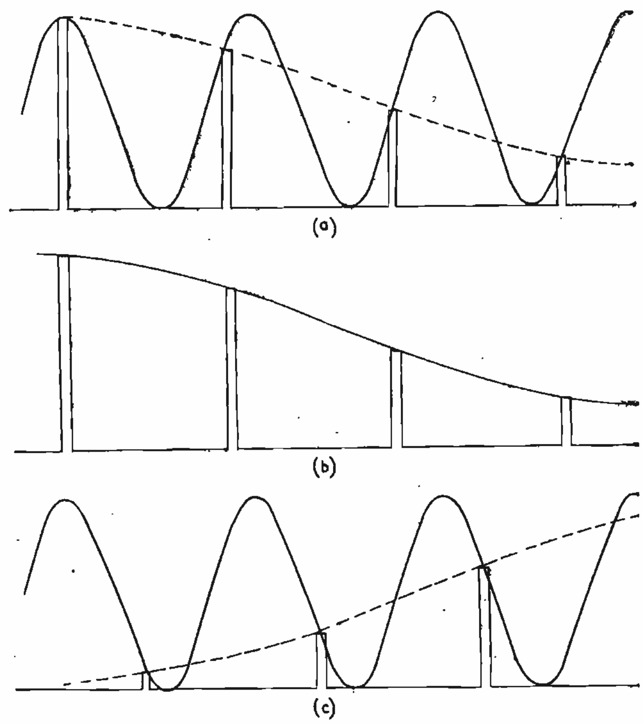

Fig. 4. (a) The result of sampling a sine wave of frequency slightly lower than the sampling frequency. (b) Sampling the difference frequency produces a result identical to (a). (c) Sampling at intermediate points produces a phase reversal of the difference frequency component

interlaced version of this complicated spectrum would produce a satisfactory picture, two facts present themselves. Firstly, unless the bandwidth is reduced to less than the sampling frequency, nothing will be gained by the process. This is true, since in this instance the sampling frequency is equal to the highest modulating frequency and the same bandwidth would have sufficed, therefore, without sampling. Secondly, Fig. 3 reveals that in using a bandwidth sufficient to include the sampling frequency, we are in fact transmitting more information than is strictly necessary, since the modulating signal spectrum occurs twice, once in its original form and once frequency-inverted or "scrambled". What happens then if the train of samples is passed through a filter of cut-off frequency *less* than the sampling rate? In theory at least, all the information is contained in the band extending up to half this rate, that is to say, half the desired spectrum is present in its normal sequence, while the other half is present, but, figuratively speaking, folded back so that the highest frequencies appear at the lower end as shown in Fig. 5. What the waveform of such a signal will look like is difficult to imagine, particularly since the sampling frequency itself has been eliminated.

In the following section it will be shown that this "folded" spectrum can be "unfolded" by means of a most ingenious artifice. For an explanation, however, it will be necessary to reconstruct the waveform, and for this purpose we shall need to know the impulsive response of the type of filter that would be used to restrict the bandwidth.

The Transmission of Samples

In order to arrive at the waveform which corresponds to the filtered spectrum of the form shown in Fig. 5, we shall make use of the principle of superposition. According to this principle, the total response of the filter is simply the sum of a number of separate responses, each of which is due to an individual sample. All we require to know is the response of the filter to a single arbitrary sample, since the response to any other sample will be of an identical form, but in general of different amplitude.

For an ideal filter, that is, a filter having a flat response over the pass band and an infinitely steep rate of cut-off, together with a linear phase characteristic, the response to a single sample is very easy to calculate. In Appendix 1 it is shown to be of the form

$$\frac{\sin \omega_c t}{\omega_c t} \quad \text{(where } \omega_c = 2\pi \times \text{ filter cut-off frequency)}$$

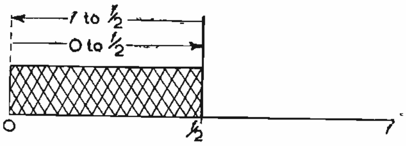

Fig. 5. Modulation frequencies from 0-f "folded" in the range 0-$f/2$

and to have a peak amplitude proportional to the amplitude of the sample. A plot of this function is shown in Fig. 6, in which the time variable has been written in terms of the cut-off frequency of the filter, and it will be seen that the response is of zero amplitude at intervals of time equal to $1/(2f_c)$ seconds both before and after the instant of the peak amplitude at which the sample is centred. Should this give the reader the impression that the filter responds before receiving the sample, the matter is clarified in Appendix 1.

This is the appearance that a single sample would have after it had passed through an ideal low-pass filter, and the output due to a train of samples will, therefore, be the sum of a series of such waveforms spaced at intervals corresponding to the sampling intervals. For the case which we are examining, the sampling rate is twice the filter cut-off frequency, that is, $2f_c$, and the interval between samples, which is of course the reciprocal of the sampling rate, is thus $1/(2f_c)$. *Therefore, at the instant when the response due to any individual sample is at its peak, the response due to all other samples is precisely zero.* This will be seen from Fig. 7(a), where the response waveforms of three successive samples of arbitrary amplitude are shown superimposed. The sum of these waveforms, which will correspond to the waveform out of the filter, is shown in Fig. 7(b), and it is this type of waveform which will be transmitted in place of the normal vision signal waveform.

In order to reconstruct the original samples from the filtered waveform, it is only necessary to perform another sampling operation at the receiving point. Provided new samples are taken at the precise times at which the maxima occur, a true measure of the amplitude of each of the original samples will be obtained, and the reconstructed samples may then be used to modulate the receiving tube in place of the normal video signal.

The explanation is in fact equally simple in terms of the frequency spectrum. If the "folded" spectrum of Fig. 5 is used to modulate a pulse train similar to that which produced it, it is easy to see that sidebands will be generated which will reproduce exactly the spectrum shown in Fig. 3, which is none other than that of the original samples.

The spectrum viewpoint illustrates an important fact which is not obvious in terms of the time function. It is not in fact necessary to use sampling pulses since only

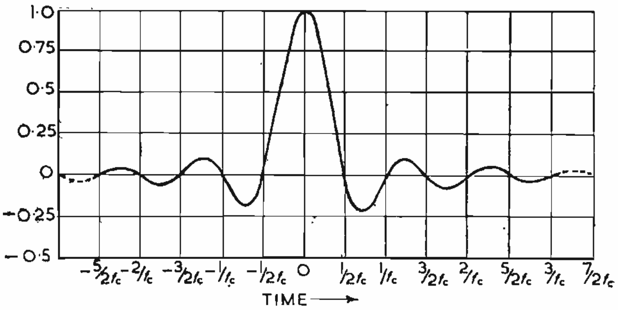

Fig. 6. Plot of the function $\frac{\sin \omega_c t}{\omega_c t}$

the D.C. term and fundamental component are used. Thus, the transmitted waveform would be unchanged if instead of the original waveform being sampled, it were modulated by the function

$$(1 + 2 \cos \omega t).$$

At the receiving point, however, pulses are necessary in order to produce the dot structure which is required for dot interlacing.

Thus, it is the second sampling process which reconstructs the samples and so permits the seemingly impossible to be achieved. Information concerning the amplitude of samples occurring at a rate of N samples per second is thus transmitted through a channel which has no response above a frequency $N/2$ cycles per second! At

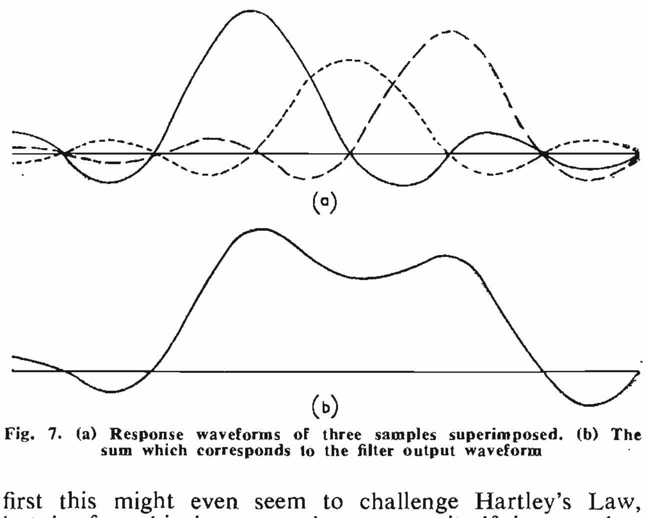

Fig. 7. (a) Response waveforms of three samples superimposed. (b) The sum which corresponds to the filter output waveform

first this might even seem to challenge Hartley's Law, but in fact this important law asserts itself in a rather subtle fashion. Having found a means of transmitting in effect N pulses per second through a bandwidth of $\frac{1}{2}N$c/s, we find that the rate of sending information has not been increased, because it takes *two* pulses to describe one sine wave. In terms of information, one cycle is worth two samples! However, we should not feel too resentful about this fact, since for a long time it has worked in our favour. In assessing the bandwidth required for a normal television picture we calculate the number of picture elements which must be transmitted in one second, and for our 405 line picture we arrive at approximately 5.6 million. Happily, we divide this figure by a factor of 2 and arrive at 2.8Mc/s for the required bandwidth, arguing that one cycle can describe two adjacent elements, for example, one white and one black. In a non-interlaced dot system, we should have to transmit 5.6 million dots or samples per second, and it is only due to the ingenious double sampling process that this could be accomplished in a bandwidth of 2.8Mc/s and so make the scoring even!

Two points of practical interest should perhaps be mentioned here, the first of which concerns the question of ideal filters. Such filters do not, of course, exist in practice, but a conventional low-pass filter may be phase-corrected to provide an impulse response which approximates very closely to the ideal response shown in Fig. 6. The second point concerns the question of synchronizing the timing of the sampling process at the receiving end with that at the transmitting end. One method[4] is to generate the sampling frequency from the line synchronizing pulses by arranging for the pulses to start an oscillator at the commencement of each line and to stop it at the end of each line. This technique will be familiar to many readers as a means of providing calibration pips on an oscillograph trace. With this method, the interlacing of dots may be achieved by arranging that the output of the triggered oscillator is phase-reversed on successive frames so that a time displacement equal to half the interval between samples is thus introduced.

Another method which has been proposed[2,5] is to choose a sampling frequency which is an integral multiple of half the line frequency, so that interlacing is automatic, as with normal line interlacing. In order to obtain this result it is necessary to derive the line frequency from the sampling frequency by means of frequency division, and, furthermore, to transmit information concerning the sampling frequency, so that the latter may be regenerated at the receiving end. A short pulse comprising a few cycles of half the sampling frequency, and transmitted during the line fly-back period, will furnish this information, provided that the sampling frequency is derived from a source of relatively high stability, and is thus substantially constant over the period of a line.

A simple example of an automatic dot interlace is shown in Fig. 8, in which a 9-line interlaced raster comprising 9 dots per line has been formed by writing dots at the rate of 4½ per line, and lines at the rate of 4½ per frame. The dots are shown as numbers, these indicating the time sequence of the four frames which are required to complete one picture.

The Limitations of Interlacing

As we have seen, the principle of interlacing, whether applied to lines or dots, permits more time to be spent in scanning each complete picture, and, therefore, more detail to be transmitted in a given bandwith. The extent to which this exchange of "time" for picture detail is profitable depends upon factors which so far have been ignored. The previous discussion was based on the assumption of a still picture, and in this instance the time taken to complete the scanning process will have no effect upon the final result, assuming, of course, that the information is stored during the process. In the case of a moving picture, however, the requirement is that the picture information should remain substantially unchanged during the period of the complete scanning process, that is, two frames in the case of simple line-interlacing, and *four* frames when this is combined with dot-interlacing.

Present-day television systems which employ line interlacing fail to meet this requirement in some circumstances, and it might be argued that the defects which result from this failure will be twice as evident if, in addition, dot-interlacing is introduced. This view, however, is probably pessimistic, since with line-interlacing the defect is a loss of vertical resolution when an object moves, and due to dot-interlacing we should expect an additional loss of horizontal resolution. Subjectively, the result will probably not be twice as bad.

The fact nevertheless remains that any improvement in overall definition which is obtained in a given bandwidth must necessarily result from an exchange, and in this instance it is detail in moving objects which will be sacrificed for the sake of increased detail in stationary parts of the picture. However, in the interpretation of many types of scene such an exchange may be well worth while.

A second assumption, which was made in the earlier discussion, was that a set of samples taken along a line would be stored at the receiving point until the second set required to complete the sampling of that particular line was received. This is, of course, also necessary for the success of normal line-interlacing, in which case the "samples" are lines. The storage of the normal type of cathode-ray tube which is used for television reception is totally inadequate to provide for the addition of two sets of samples, spaced in time by 1/50second. That is to say, the afterglow of such tubes is very short compared with this time, and it is the human eye that must perform

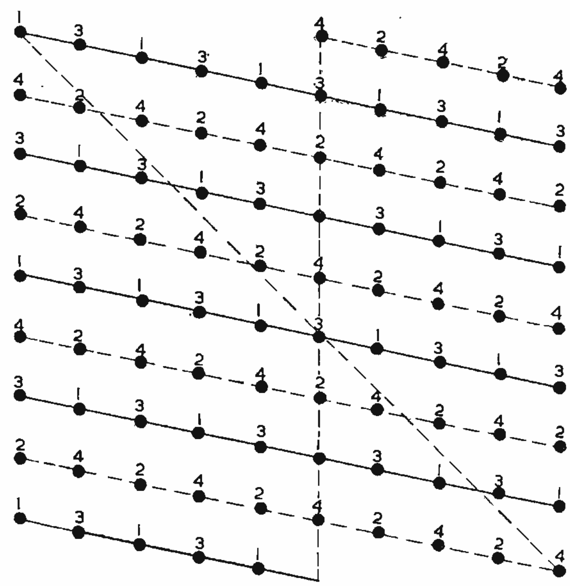

Fig. 8. Simple raster showing dot sequence in an interlaced dot system

the addition by virtue of persistence of vision. The ability of the human eye to store a picture for 1/50second is evident from the fact that, over a useful range of brightness, flicker is not evident when viewing a television picture comprising 50 frames per second. However, for the complete addition of two sets of samples spaced in time by 1/50second, and lasting for 1/50second, the eye would be required to store picture information for 1/25second, and at the brightness level which is normally required for viewing, this is not the case.

This is evident from the fact that a set of horizontal converging lines displayed on a television receiver exhibit a noticeable flutter in the region where the lines have converged to have a spacing comparable with that of the scanning lines on a single frame, i.e., 200 lines in the British system. This effect may be explained in terms of the sampling theory which was discussed earlier, when it was shown that samples taken at a frequency comparable with that of the waveform being sampled would produce a difference frequency component (see Fig. 4). Complete addition of a further set of samples taken at intermediate points would eliminate the difference frequency, but it is apparent that with incomplete storage the difference frequency components will not exactly cancel, and each component will be visible on alternate frames, at the rate of 25 per second. It is the 25c/s phenomenon which gives rise to the flutter referred to above, and this would not exist if either the eye or the receiving tube had a sufficiently long decay time. However, with the decay time increased sufficiently there would be no point in adopting interlacing.

The defect referred to might be much more serious if dot-interlacing is introduced, in which case four frames are required to complete a picture, and twice the storage time is thus required to integrate the picture information. In Fig. 8 it will be seen that alternate samples along each line are presented only every third frame, but the situation is no doubt relieved considerably due to the fact that intermediate samples are presented on adjacent lines every alternate frame. The net result will probably be that fine repetitive detail, whether horizontal or vertical, will give rise to beat patterns, which will be accompanied by slight flicker at the higher brilliance levels.

Finally, there is the phenomenon commonly referred to as "crawling." In the case of line-interlacing, if the eye of the viewer is caused to scan slowly in a vertical direction, the raster appears to have lost interlace and to be drifting slowly in the direction in which the eye is scanning. The reason for this is that the image of each frame is retained as it is built up, on the retina of the eye, and is present when the succeeding frame comprising interlaced lines has been presented. Whether or not the two images combine to produce an interlaced image on the retina depends entirely on whether or not the eye has moved during the presentation of the two successive scans. Once the scanning spot has passed the point on which attention is focused, there is nothing on which the eye can fix attention, and it is, therefore, not surprising that when the next scan is presented there is a strong tendency for the eye to fix attention upon the newly presented lines so as to cause complete registration of the two images. The result is that the raster portraying a still picture appears to have an instability associated with the interlace, while a picture containing a component of vertical movement may appear as being non-interlaced with the line structure "crawling" in the manner referred to above. This probably would not happen if the receiving tube was storing the picture to any appreciable extent over the frame period.

In dot-interlacing, the image stored on the retina due to a single frame will be comprised of dots, for example, the dots numbered, 1, in Fig. 8. The succeeding frame will comprise the dots numbered, 2, and it will be seen, that the displacement necessary to cause registration of these two images would be in a diagonal direction, either from top right to bottom left, or top left to bottom right. Continued movement in either of these directions will also bring about a further registration with frames 3 and 4. Thus, the phenomenon of "crawling" with the attendant loss of interlace, will exist only when the eye is scanning down in a diagonal direction. It will be seen that no such sequential registration can occur with purely vertical or horizontal movement, that is to say, it will not be possible to induce the apparent loss of line-interlacing or dot-interlacing independently. Since diagonal scanning is not a very natural process as far as the eye is concerned, the dot structures as shown in Fig. 8 may well result in a marked improvement in the apparent stability of the interlace, but should the eye be *induced* to scan diagonally at the appropriate speed, only one quarter of the total number of picture elements would appear to be reproduced.

Application to Colour Television

The sampling process, which is fundamental to dot-interlacing, may very easily be extended to facilitate the transmission of two or more separate signals through a single channel on a time sharing basis. There is thus an immediate application in colour television, in which the basic problem in the three-colour system is to transmit three separate signals over a single circuit. Such a system has been developed by the Radio Corporation of America, and a detailed description has been published,[1] which it is proposed to describe briefly.

For the purpose of a time multiplex system, in which N signals are to be transmitted over a single circuit, the sampling frequency will remain as already defined, but the cut-off frequency of the filter through which the samples are transmitted will be multiplied by N. As will be seen from Fig. 6, this will have the effect of reducing the *duration* of samples appearing at the output of the filter by the factor N, and since the repetition rate is unchanged, there will thus be created a time interval into which $N-1$ additional independent samples may be inserted.

This is the general case. In the particular case of the RCA three-colour system, three separate signals are obtained from three camera tubes, each of which is related to one of the primary colours, red, blue and green. By way of example, we will suppose that each of these signals has a bandwidth extending from 0 to 3Mc/s. Taking first the red signal, this will be sampled at a rate of 3Mc/s, so that the interval between the samples is $1/3\mu$sec. Instead of passing the samples through a filter with a cut-off frequency of half the sampling rate, as described previously, three times the cut-off frequency will be chosen, that is, 4·5Mc/s. From Fig. 6 it may be deduced that in this case the "zeros" will occur at time intervals of $1/9\mu$sec on either side of the instant of maximum amplitude. If the green signal is sampled and filtered in a similar manner, but the times of sampling are advanced (or delayed) by $1/9\mu$sec., the maxima of the "green" samples will occur when the "red" samples are at zero amplitude. Similarly, the "blue" samples may be displaced in time by a further $1/9\mu$sec, that is, $2/9\mu$sec leading or lagging on the "red" signal, and the condition will still hold that when any one sample is at a maximum amplitude, the contributions of all others will be zero. Thus, the three signals may be combined and transmitted over a single channel, and no cross-talk will be introduced at the instants at which individual samples are at maximum amplitude. Clearly, it is immaterial to the result, whether the samples are filtered before or after they are combined, and the latter arrangement is adopted in practice since only one filter is required.

At the receiving point the red signal is extracted by sampling the combined signal at the instants of time at which the red samples are at maximum amplitude, and similarly, in the case of the blue and green signals. The three signals having thus been separated may then be applied either to three separate colour tubes, each of which will provide the appropriate coloured image, or, as with the latest RCA development, to a single three-colour tube.

In the example given above, a three-colour signal which would normally have required a bandwidth of 9Mc/s is, therefore, transmitted in a bandwidth of 4·5Mc/s; that is, 1·5 times the bandwidth that would be required for a conventional monochrome picture having the same definition. These figures which have been given to illustrate the principle of the RCA colour system, do not correspond with those which are actually adopted in practice. In fact, a further economy is introduced into the RCA system in order to reduce the bandwidth to no more than that which is required for the American standard of monochrome transmission. In these circumstances, the colour transmission may be received on a standard "black and white" receiver, without the latter requiring any modification. The term "compatible" has been adopted in America to describe a colour system which provides this facility. The video bandwidth which is required for the American system of monochrome transmission is 4Mc/s, so that a dot-interlaced colour system as described above would require a video bandwith of 6Mc/s to have the same definition. To make the system "compatible," however, a system termed "mixed highs" has been used. Briefly, the principle is this:

The spectrum of each of the three colour signals is reduced by means of a filter from 4Mc/s to 2Mc/s, so that the definition of the coloured picture is reduced proportionately. However, the components over the range 2Mc/s to 4Mc/s which are rejected by the filters are not discarded, but are combined to produce black and white information which relates only to fine detail. The latter signal, which is termed the "mixed highs" signal, may be transmitted together with the combined colour signals in a bandwidth of 4Mc/s, and it is contended that the result is completely satisfactory, since the visual acuity of the eye in terms of colour is substantially less than it is in the case of "black and white."

It will be noted that the sampling frequency for the individual colour signals should, strictly speaking, be 4Mc/s, so that the combined sampling rate should be 12Mc/s. Since the samples are transmitted with the bandwidth restricted to 4Mc/s, whereas 6Mc/s is actually required, the filtered samples will be of excessive duration and some degree of cross-talk will, therefore exist. In order to reduce the degree of cross-talk, a slightly lower sampling frequency is in fact adopted.

Appendix

A pulse of infinitesimally short duration, but of infinite amplitude, has a flat frequency spectrum which extends from zero to infinity, and it comprises the sum of all the cosine waves that are contained in such a spectrum.

It is known as the impulse function and may be written

$$\int_0^\infty \cos \omega t . d\omega$$

If such a pulse is applied to an ideal low-pass filter with a cut-off frequency, ω_c, the output of the filter will be:

$$\int_0^{\omega_c} \cos \omega t . d\omega$$

$$= \frac{\sin \omega_c t}{t}$$

Multiplying both numerator and denominator by ω_c gives:

$$\omega_c . \frac{\sin \omega_c t}{\omega_c t}$$

The form is thus $\sin x/x$, and the amplitude is proportional to the bandwidth of the low-pass filter.

This result may be applied readily to the case of a rectangular pulse of finite amplitude and duration, provided that the duration is short compared with that of a cycle of the filter cut-off frequency. Over such a frequency range the pulse spectrum is of substantially constant amplitude and is, therefore, virtually identical to that of the true impulse function. We may in fact attribute to the pulse a cut-off frequency which is equal to the reciprocal of its duration, and therefore its amplitude after the filter will be reduced by a factor equal to the ratio of the two cut-off frequencies.

It will be noted from Fig. 6 that the ripples occur before the main pulse. This does not mean that the ripples start before the pulse is applied to the filter, but simply that the ripples arrive at the *output* of the filter before the main pulse. If a practical filter was phase-corrected to have a perfectly linear phase characteristic, an infinite number of phase-correcting sections would have to be used and the main pulse would then suffer an infinite delay. There would, therefore, be ample time for the ripples to arrive first!

A practical filter complete with phase-correction might introduce a delay equal to the period of about three cycles of the cut-off frequency, and, therefore, only three ripples will occur before the main pulse. This is, however, sufficient to provide an adequate degree of symmetry for practical purposes.

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An Emission Stabilizer with D.C. Heater Supply

By D. E. Brown *

The unit described provides a D.C. heater supply of 20 watts suitable for use with an ion source. Feedback is incorporated to stabilize the total emission from the heater and a variable electron accelerator voltage is provided. Stability of emission current is ± 0·4 per cent for a mains supply change of ± 10 per cent. The A.C. modulation of the electron current is 0·2 per cent.

When a heater is supplied from an A.C. voltage source of frequency f the temperature of the heater, and therefore, the emission from it will vary at a frequency $2f$. The magnitude of the emission variation will depend on several factors; the thermal capacity and rate of heat loss of the heater and operating temperature. In a practical case this variation can be as high as ± 15 per cent of the average emission current.

In the design of an emission regulator this large A.C. component of the emission current can lead to serious difficulty. The current to be stabilized must pass through a resistor in order to provide a voltage for comparison with a stable reference. In order to provide adequate stability the reference voltage is of the order of 50 to 100 volts. If this voltage is used to back-off the voltage due to the emission current, the first valve of the stabilizer amplifier will have up to 30 volts, peak to peak ripple on the grid. This can be reduced by an *RC* filter network but too long a time-constant here leads to oscillation of the stabilizer. We also have this large A.C. component present on the electron accelerator voltage and it is difficult to measure appearance potentials accurately.

The circuit to be described is an attempt to overcome these difficulties by the use of a D.C. heater supply.

* *AERE, Harwell*

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Circuit Description

The circuit used is shown in the diagram. The valves V_1 and V_2 act as a multivibrator with cross coupling between screens and grids. The frequency of oscillation is approximately 1kc/s. A pulse transformer T_1 is connected between the anodes and supplies substantially square pulses of current to the bridge rectifier which feeds the heater. Since the rectifier system is full-wave and the voltage pulses are square, very little A.C. ripple is present in the output and no filtering is required.

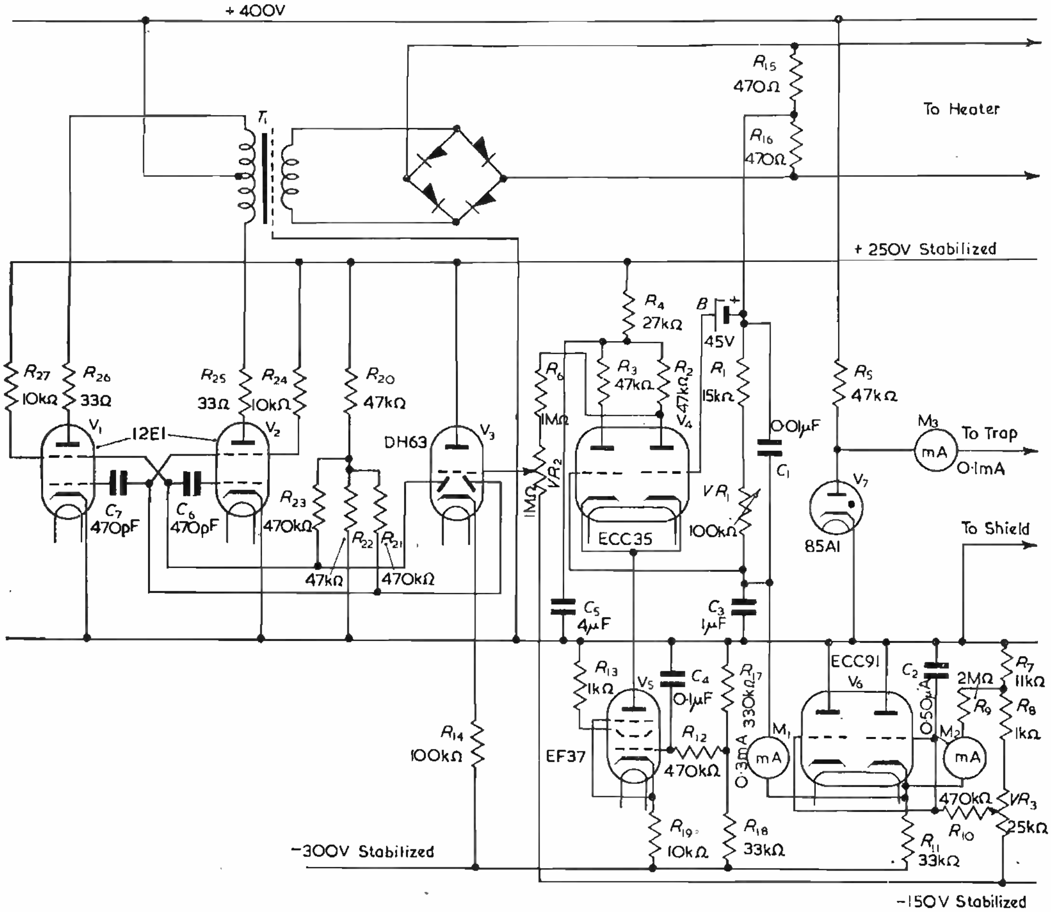
The voltage supplied to the heater is dependent upon the current turned on in valves V_1 and V_2 during their conduction periods. This is controlled by "catching" the grids on the diodes of the double diode triode V_3 at some potential below that of the cathodes. Therefore in order to regulate the heater voltage and hence the emission current we have to vary the potential of the control grid of V_3 which is connected as a cathode-follower.

The emission current from the heater is passed through R_1 and VR_1 and the voltage drop across them is backed off against a 45 volt battery *B*. The error signal is then applied between the grids of valve V_4 which is connected as a "long-tailed pair" with the pentode V_5 as common cathode load. The amplified signal is then fed from the anode of V_4 through the voltage dividing network R_6 and VR_2 to the grid of V_3, thus controlling the heater voltage and stabilizing the emission. The potentiometer VR_2 is used in the dividing network to provide a means of slowly raising the heater voltage when "outgassing" the heater. For normal operation this control is set for maximum resistance between grid of V_3 and the negative H.T. rail.

In order to vary the electron accelerator voltage in the ion source it is necessary to vary the voltage between heater and shield. Now the emission regulator works in such a way as to ensure a drop of 45 volts across R_1 and VR_1 whatever the current may be. Hence in order to vary the accelerator voltage it is necessary to vary the potential of the negative end of VR_1. This is done by connecting this point to the cathode of V_6 which is strapped as a cathode-follower and varying the potential of the grids by means of VR_3. The heater potential will always be 45 volts above that of the cathode of V_6. Therefore, in order to vary this from zero to -100 volts with respect to shield, the grid of V_6 must be moved from -50 to -150 volts. An approximate value of the accelerator voltage can be read on M_2 which is connected as a voltmeter between the cathode of V_6 and a point 45 volts negative with respect to shield. Since the common cathode potential of V_4 is varying by 100 volts, a change in cathode current would take place if the cathode load were a resistor. To avoid this, the cathode load is a pentode V_5, the current of which is stabilized by means of R_{17}, R_{18} and R_{19}.

The pulse transformer T_1 should have an electrostatic screen in order to avoid feeding a square wave on to the heater through the capacitance of the windings. The small amount fed through can be reduced by connecting C_1 from the heater centre tap to the shield.

Power supplies for the unit are obtained in a conventional manner from a mains transformer, the primary insulation of which is adequate for 2kV working.



Emission regulator for mass spectrometer

Conclusions

The emission stabilizer described is capable of supplying up to 20 watts of heater power. The stability of the emission current is ± 0·4 per cent for a mains input variation of 10 per cent. The A.C. modulation of the electron current is about 0·2 per cent peak-to-peak. The unit can be used for the measurement of appearance potentials, but for accurate work a valve-voltmeter must be built in to measure the voltage between the centre tap of the heater and the shield.

Acknowledgments

The author is indebted to the following:—

Mr. Florida of A.E.R.E for originally suggesting the use of a multivibrator as a convenient D.C. supply.

Mr. Grapes of T.R.E. for designing the pulse transformer.

Mr. H. G. May of A.E.R.E. for building the unit.

Mr. G. Page of A.E.R.E. for drawing my attention to this problem.

A Transductor-Controlled Stabilizer

For Medium Direct Currents

By H. G. Smith,* B.Sc.

IT is often necessary to stabilize a D.C. supply of several hundred milliamperes to several amperes at a voltage of up to about 20 volts. Large accumulators are often used in research applications, but these are cumbersome and in need of constant maintenance. Examples which commonly occur are the stabilization of valve heater supplies for D.C. amplifiers, of lamp supplies in photometric, photographic or photo-electric work, and of the supplies for the provision of constant electromagnetic fields. These types of output are not satisfactorily within the range of stabilizers using thermionic valves as these are more suitable for the higher voltage and lower current range.

It is, perhaps, not generally known that the transductor may be adapted to stabilize this medium-current type of supply to a fairly high degree. The transductor, as used in the present instance, without self-excitation, provides a constant-current source of high incremental output impedance in contrast with the normal constant-voltage stabilizer of low output impedance. Each type of source will supply constant-power to a load of fixed resistance. If the resistance of the load should change slightly, due to ageing or temperature effects, the power dissipated will increase with increased load resistance, in the case of the constant-current source, and decrease in the case of the constant-voltage source, but for small changes in load resistance the change in power is practically the same in each case. If, as happens sometimes in practice, it is desired to supply constant power to a fixed load over a varying length of cable the constant-current source is obviously the more suitable. An additional point of some importance when feeding valve heaters or lamps which are switched on and off intermittently is that the normal current surge, due to the low resistance of the load when cold, is almost completely eliminated with a constant-current source.

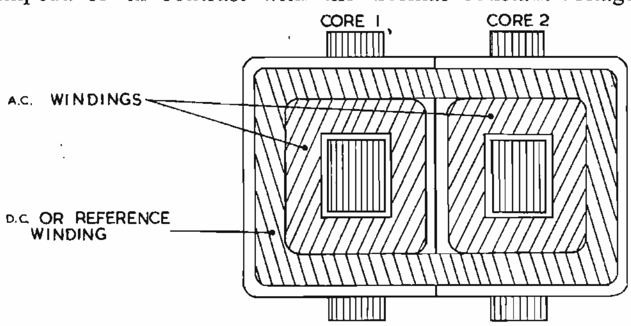


Fig. 1. Transductor construction

The Transductor

The transductor is similar to the iron-cored saturable-reactor, but instead of obtaining control from the change of incremental permeability of the core, the transductor works with the A.C. flux swing, in the absence of D.C. excitation, just below saturation, and control is obtained by distortion of the current waveform as the D.C. excitation pushes the flux wave into the saturation region.

The transductor takes the form of two identical, easily-saturable, magnetic circuits. In the present case two separate cores are used, but it is possible to use the two halves of a three-legged core. Each core has an A.C. winding, with equal numbers of turns on each core, connected in series opposition with respect to a D.C. winding which embraces both cores. The D.C. could be applied to separate windings on each core, connected in series, but the present arrangement ensures that the voltage of fundamental frequency induced on the D.C. side is cancelled in each turn and does not reach the high value, across each half of the D.C. winding, that it would do otherwise, due to the high step-up ratio from the A.C. to the D.C. side. The arrangement is shown in Fig. 1.

The relationship between the direct current and the alternating current is such that the number of D.C. ampere-turns applied to each core is approximately equal to the number of A.C. ampere-turns on each core, where the A.C. is measured as the mean of a half-wave. With care taken in the core construction, using a core material having a rectangular *BH* curve, the relationship is quite accurate and linear. The arrangement is commonly used as a direct current transformer. By a suitable choice of the number of turns on the D.C. side, a step-up or step-down in current may be obtained. When a load is incorporated in the A.C. side, power amplification is obtained with respect to the power on the D.C. side.

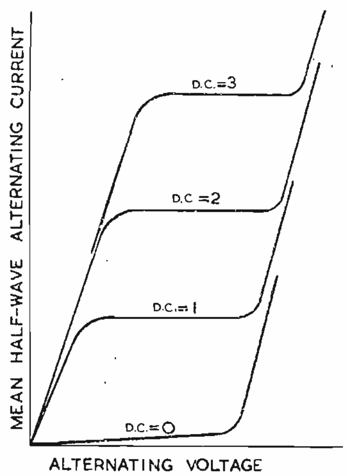


Fig. 2. Typical transductor characteristics

Stabilization of Mean Current

If the excitation on the D.C. side is kept constant, as described later, and the A.C. side is connected to an A.C. supply in series with a resistive load, then the mean half-wave alternating current through the load will remain almost constant irrespective of large variations in the A.C. supply voltage and frequency and in the load resistance. Fig. 2 shows the variation of load current with supply voltage for different D.C. excitations, with the load resistance and the frequency constant. When the load current is rectified, normally with a full-wave metal rectifier, the output current is pulsating but the mean value is stable with respect to supply and load variations. This type of source is suitable for an electro-chemical process if a stable direct current is required, but for applications like valve and lamp supplies the R.M.S. value of the current must be stabilized. This is not obtained in the case above, because as the supply voltage and frequency and the load resistance vary, the waveform of the pulsating output current changes, the mean remaining constant, so that the relationship between the mean value and the R.M.S. value does not remain constant. This is illustrated by the oscillograms of Figs. 3(a) and 3(b), in which the mean values of the D.C. outputs are equal to within 1 per cent, as measured by a moving-coil instrument, although the supply voltage

* *British Scientific Instrument Research Association.*

for Fig. 3(b) is half that for Fig. 3(a). It is interesting to note here that the mean flux in the cores in the presence of the combined A.C. and D.C. magnetization is not equal to that produced by the D.C. magnetization alone, as might be expected, but is dependent on the alternating flux. Thus, as the A.C. supply voltage or frequency or the load resistance changes, the mean flux in the cores changes. This means that the cores are saturated for a larger or smaller part of the alternating cycle, as the conditions change, so that the waveform of the output current changes and in doing so maintains the mean output current constant

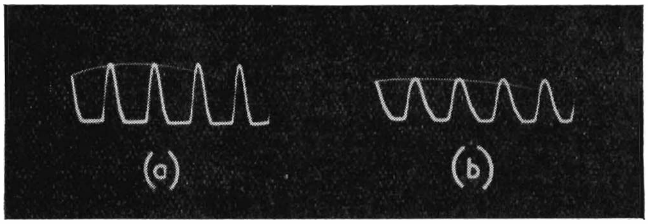


Fig. 3. Effect on the rectified output current, before smoothing, of a 2/1 change in supply voltage. (a) High supply voltage. (b) Low supply voltage

or nearly so. These properties are the result of inherent negative feedback in the action of the transductor.

Stabilization of R.M.S. Current

The method adopted to obtain stabilization of the R.M.S. value of the D.C. output is to smooth the output, when stabilization of both mean and R.M.S. values is obtained, since they are sensibly equal. For a low-voltage, heavy-current application, the inductance of the smoothing choke is necessarily low, so that high-value smoothing capacitors are needed.

Design Factors

If the number of turns on the D.C. winding of the transductor is large compared with the number of turns on the A.C. windings, the reference current in the D.C. winding is correspondingly small compared with the output current. This makes possible the use of an electronically-stabilized H.T. source delivering, say, 20mA to supply the reference current, while the H.T. source can be used simultaneously for its normal purpose. The use of a high voltage reference source is desirable in that it reduces the recovery time of the stabilizer and allows the use of stable dropping resistors in series with the reference winding to help swamp the temperature dependence of the resistance of the winding. The use of a shunted "Thermistor" in series with the reference winding for temperature compensation is even more effective. Probably the neatest arrangment is to use a network which supplies constant-current to the reference winding, although it precludes using the reference source simultaneously as a voltage stabilizer if the resistance of the reference winding should vary much. In this arrangement a low temperature-coefficient wire-wound resistor is connected in series with the transductor reference winding. The normal potential divider is removed from the output of the H.T. stabilizer and the potential divider formed by the wire-wound resistor and the reference winding connected in its place, so that the voltage across the wire-wound resistor is stabilized. The current in the wire-wound resistor is, therefore, stabilized and since this current flows through the reference winding of the transductor, this current is also stabilized.

Any method of stabilizing the current in the reference winding will suffice, but the stabilization ratio of this current should not be less than about 200, otherwise the properties of the transductor section will be wasted since the overall stabilization ratio is obviously worse than that of either the reference current or the transductor portion alone (see Appendix 2).

To ensure good stabilization from the transductor itself it is essential to use a high-permeability core material which exhibits sudden saturation. In addition, the core construction must be such that air-gaps are minimized, and the whole core saturates at once. Suitable materials are "Mumetal", "Permalloy C", and "H.C.R." While the best form may be the spirally-wound strip core, this necessitates toroidal windings which are difficult to construct. It is, therefore, more convenient to use overlapping E-type laminations or overlapping T and U laminations for the smaller sizes which are available in all three materials, and to use cores built up from overlapping strips of "H.C.R." for the larger sizes. The higher saturation flux density of "H.C.R." gives increased output for the same size core, compared with "Mumetal" or "Permalloy C". The geometrical proportions of the laminations or strips should be such that the cross-section of the magnetic circuit of the built-up core is as uniform as possible throughout its length.

Description and Performance of Stabilizer to Supply 0·6A

The circuit of a typical stabilizer which has been used to supply valve heaters in a D.C. amplifier is shown in Fig. 4, and is now described, while the general design procedure for a transductor current-stabilizer is given in Appendix 1. The transductor is of the twin-core type, each core consisting of a stack 1½in. deep of T and U stampings of Mumetal, 0·015in. thick, type M.E.A. No. 4. The assembly is made with the tips of the laminations fully overlapped and with alternate pairs of T's and U's reversed. An A.C. winding is wound first on each core, with 285 turns of 22 S.W.G. D.S.C. copper wire. These are connected in series opposition with respect to the reference winding, which is wound over both A.C. windings, after the bobbins have been butted together. The reference winding has 8,000 turns of 38 S.W.G. E. & S.S.C. copper wire resistance 2,700 ohms, and requires a current of 22mA for an output current of 0·6A.

The primary of the mains transformer is designed to work from a maximum supply voltage of 5 per cent above mains voltage.

The reference source consisted of a 650 volt D.C. supply stabilized with a series valve controlled by two stages of valve amplification, the ultimate reference being a high-stability neon tube. The stabilized output of 300 volts, which had a stabilization ratio of 330:1, could be fed to the reference winding through a wire-wound dropping resistor which provided some temperature compensation

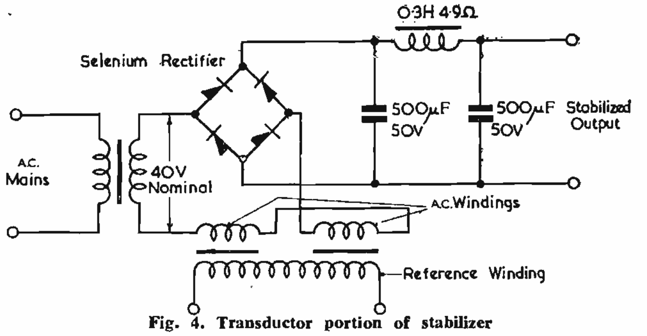


Fig. 4. Transductor portion of stabilizer

against resistance variation as the reference winding became warm, or, alternatively, a shunted "Thermistor" could be included to provide a better degree of temperature compensation. The "Thermistor" should be in good thermal contact with the reference winding and shielded from draughts. In each case it was possible at the same time to use the 300 volt stabilized source to supply H.T. to the valves of the D.C. amplifier. Fig. 5(a) shows the component values suitable for obtaining an output current of 0·6A by the second method. For a different output current the temperature-compensation network must be modified, as the self-heating effect on the "Thermistor" will be different. The most satisfactory arrangement was to use a separate H.T. stabilizer connected, as described above, to supply constant current to the reference winding. It was necessary to decouple the reference winding and the reference source, to prevent the harmonic voltages induced in the reference winding, due to the transductor action, from interfering with the operation of the reference source. The component values for an output current of 0·6A, including those necessary for adjustment are shown in Fig. 5(b).

With a transductor output of 0·6A at 6·3V the complete stabilizer provided a stabilization ratio of 100:1 when the supply voltage was varied from 10 per cent below normal to 5 per cent above normal. From a theoretical point of view the same effect would be obtained with similar variations in supply frequency, but in the reverse direction. For the same output current, namely 0·6A, when the load resistance was varied from a short circuit to 33 ohms so that the output voltage rose from zero to approximately 20 volts, the drop in current was 2 per cent.

The same stabilizer may be used for different output currents by adjusting the reference current, since the two are approximately proportional, as mentioned above, but the best performance is obtained from 0·4 to 0·6A output.

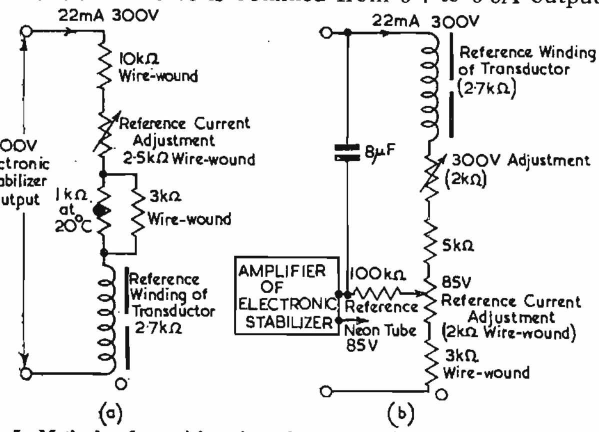


Fig. 5. Methods of supplying the reference winding. (a) Constant voltage with temperature compensation. (b) Constant current

The variation of output voltage with temperature amounted to a decrease of 4·5mV per degree Centigrade rise in temperature when the output was 0·6A at 6·3V, and a wire-wound resistor was used in series with the reference winding. Using the "Thermistor" compensation the output was constant to within 5mV over the range of ambient temperatures from 10°C to 35°C. When constant current was supplied to the reference winding, the output decreased 1mV per degree Centrigrade rise in temperature.

On a seven-day test the output was constant to within plus or minus 1 part in 800, while the temperature varied by 10·5°C, the supply frequency by 2·6 per cent, and the supply voltage by 6·5 per cent.

When the supply voltage was suddenly changed by 10 per cent, or the load suddenly changed from zero to 10·5 ohms, the recovery time of the output was approximately 0·2 seconds. The ripple voltage was approximately 40mV R.M.S.

For an output of 0·6A the transductor requires about 30VA from the mains supply, and 6 watts from the reference source, one-third of which is used in the reference winding itself and the remainder in the dropping resistors.

Acknowledgments

The author wishes to thank the Director and Council of the British Scientific Instrument Research Association for permission to publish the above information, Dr. A. J. Maddock, in whose department the work was carried out, and Mr. R. P. B. Yandell for his helpful advice.

Apppendices

(1) General Design of Transductor for a Current Stabilizer

The design data will include the maximum output current and voltage, the nominal supply voltage and frequency, the voltage of the reference source, and its maximum permissible current drain.

The following design steps provide a guide only since a compromise has to be made between the size of the transductor, the stabilization ratio, and the power gain, which for a given output determines the power provided by the reference source. For more information reference must be made to the literature on transductor design, from which a useful selection is given later.

1. For a trial core size, estimate the maximum resistance in the output circuit, including the resistance of the A.C. windings of the transductor, the rectifier resistance, the choke resistance and the maximum load resistance.
2. Determine the alternating voltage required to deliver 25 per cent more than the maximum output required into the maximum resistance in the output circuit.
3. Increase this voltage by the percentage by which the lowest supply voltage to be catered for falls short of the normal supply voltage to give the normal operating voltage of the transductor, i.e., the secondary voltage of the mains transformer.
4. Calculate the number of turns (N_a) on the A.C. winding for each core from the formula $N_a = \dfrac{V \times 10^8}{4{\cdot}44\,BAf}$ where V is half the normal operating voltage of the transductor as determined in (3), A is the effective cross-sectional area of each core in sq.cm, and f is the supply frequency. The maximum working A.C. flux density B is chosen to be at the knee of the BH curve for the core, and may be taken as 5,000 lines/sq.cm for "Mumetal" or "Permalloy C", and 13,000 lines/sq.cm for "H.C.R.", provided a good core construction is used.
5. Check that the magnetizing current of the transductor (with zero reference current) is well below the minimum current to be stabilized. The impedance of the transductor in this case may be taken as the reactance $\dfrac{2 \times 1{\cdot}257\omega N_a^2 A\mu}{l \times 10^8}$ where μ is the core permeabiltiy, l is the length of each magnetic circuit in cm, and $\omega = 2\pi f$.
6. Determine the gauge wire for the A.C. windings on the basis of current-carrying capacity and space available.
7. Determine the number of turns and the gauge of wire for the reference winding on the basis of current carrying capacity of wire, space available, reference voltage, and the fact that for each core the number of ampere-turns on the reference side is approximately equal to the number of ampere-turns on the A.C. side.

(2) Calculation of Overall Stabilization Ratio

If the stabilization ratio of the reference current be s_1 and that of the transductor alone be s_2, then the overall stabilization ratio S is given by

$$S = \frac{s_1 s_2}{s_1 + s_2}$$

For the stabilizer described above, $s_1 = 330$, $s_2 = 135$ so that the overall stabilization ratio is calculated to be 96, which agrees well with the measured value of 100.

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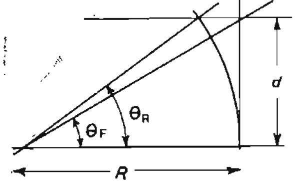
Linear Scanning with Wide-Angled Cathode-Ray Tubes

By K. G. Beauchamp,* A.M.Brit.I.R.E.

IT is well known that in order to produce a linear trace in a magnetically deflected cathode-ray tube, free from velocity modulation, the current through the deflector coil windings must have a linear rising characteristic, i.e., be of sawtooth waveform.

This assumption, however, is only valid for small angles of deflexion with tubes having a radius of curvature of the tube face equal to the distance from the screen centre to the axis of deflexion.

With the wide-angled, nearly flat-faced tubes, commonly used in the U.S.A. and now beginning to be manufactured in this country, an appreciable departure from a linear sawtooth waveform is desirable if good linearity is to be maintained over the entire screen area.



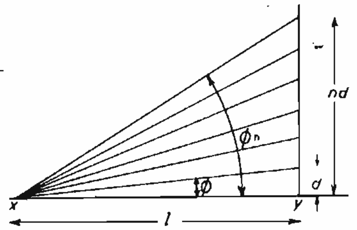


Fig. 1 (left). Comparison of deflexion angle required for flat and round-faced C.R.T. Fig. 2 (right). Determination of form of scanning current to produce a linear scan

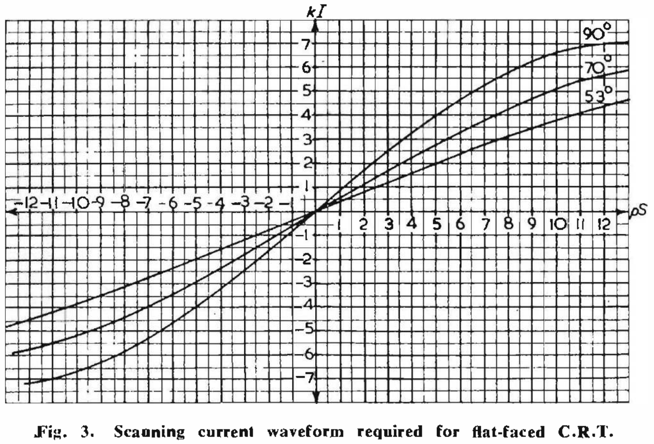


Fig. 3. Scanning current waveform required for flat-faced C.R.T.

Reduction of Scanning Current Required

Consideration of Fig. 1 will show that in order to produce the same (subjective) length of trace with round and flat-faced tubes, angle θ_R requires reduction to angle θ_F, resulting in a reduction of scanning current from $I_R = k \sin \theta_R$ to $I_F = k \sin \theta_F$ (see Appendix) .... (1)

from diagrams, $d = R \tan \theta_F$

but $d/R = \sin \theta_R \therefore \sin \theta_R = \tan \theta_F$ .. (2)

and from (1)

$$I_R = k \tan \theta_F \text{ and } I_F = k \sin \theta_F$$

* *The General Electric Co., Ltd.*

This gives an expression for reduction in scanning current δI,

$$\delta I = \frac{I_R - I_F}{I_R} \, 100 \text{ per cent} \quad \ldots\ldots\ldots \quad (3)$$

A measure of standardization has been reached in this country and the U.S.A. as to the size of maximum scanning angle in use or proposed. This has resulted in three standard angles being employed, namely 53°, 70° and 90°.

Table 1 has been obtained by applying Equation (3) to these three scanning angles.

Table 1

$2\theta_F$	δI
53	10·5
70	18·1
90	29·3

Derivation of Scanning Waveform

In order to determine the correct form of scanning current required in order to produce a linear scan, let us divide the flat screen into a number of equal increments d (Fig. 2). Let the angle each point of increment makes with axis xy be ϕ_n, then:

$$\phi_n = \tan^{-1} nd/l \quad \ldots\ldots\ldots\ldots \quad (4)$$

where n is an integer.

Commencing with a small angle, say 5°, then $d/l = 0{\cdot}0875$ and Equation (4) simplifies to:

$$\phi_n = \tan^{-1} 0{\cdot}0875 \, n \quad \ldots\ldots\ldots\ldots \quad (5)$$

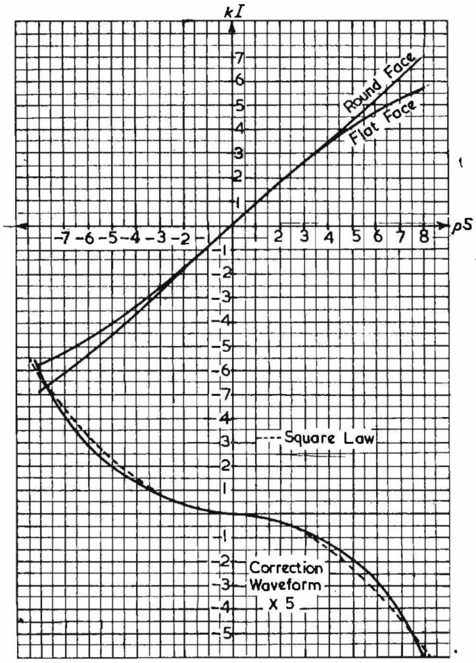


Fig. 4. Correcting waveform for round and flat-faced C.R.T.

Now from the Appendix it will be seen that the scanning angle:

$$\sin \phi_n = \frac{0{\cdot}3\,HL}{\sqrt{E}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

As field H at any instant is proportional to scanning current I, and also as $0{\cdot}3L/\sqrt{E}$ is a constant then:

$$I = P \sin \phi_n \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

where P is a constant.

From Equations (5) and (7) scanning current I for any angle ϕ_n can be derived and the results have been plotted in Fig. 3 for tubes of the same overall screen diameter. (Arbitrary scales of current and distance have been used).

It will be observed that even for relatively small scanning angles the flat nature of the tube face demands some departure from a linear rise of current.

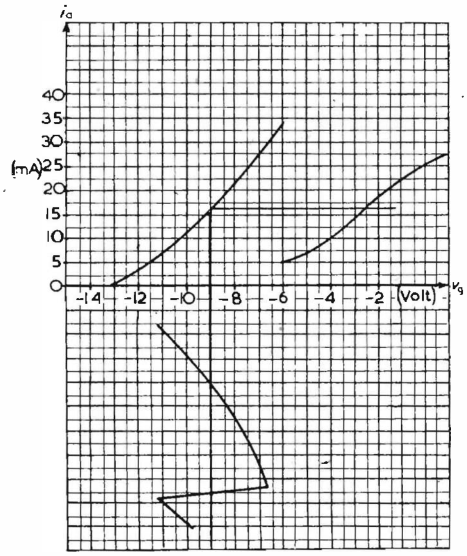


Fig. 5. Exponential waveform plotted on i_a/v_g curve

Linearizing the Trace

In order to produce a waveform such as Fig. 3 from a linear sawtooth current generator a suitably shaped correcting waveform can be added or subtracted from the linear rise of current.

This is derived in Fig. 4 where it is seen that this correcting waveform closely follows a square law, (shown dotted for comparison). The square wave of potential normally used to produce a sawtooth current through a pure inductance thus requires a parabolic content in order that the shape of Fig. 3 be realized.

This may be obtained by inserting a capacitor in series with the deflexion coils. The required capacitance is given by:

$$C = 1/v \,.\int_0^{T/2} .\, i\,dt \quad \ldots\ldots\ldots\ldots \quad (8)$$

Where v is the correcting potential across the capacitor and is parabolic in shape, also $i = kt$ = slope of sawtooth current waveform.

For the line scanning circuit this method is especially suitable where an efficiency diode is employed. Here a D.C. blocking capacitor is required in series with the deflexion coils and its value may be chosen to give the flat-faced correction outlined above. A suitable value will be found to lie between 0·1 and 1·0μF and can be selected experimentally.

An alternative method, which may be used where a sawtooth voltage generator is used to drive a current output stage, is given below.

The sawtooth voltage is normally derived from the charge or discharge of a capacitor, and as such will be exponential in form.

If this be applied to a valve operating on the lower part of its i_a/v_g characteristic (Fig. 5) a degree of non-linearity can be obtained at the commencement and end of the current rise such as to effect a marked improvement to the subjective linearity of scan.

In a practical case the operating point on the i_a/v_g characteristic may be made variable by alteration of cathode-bias thus providing a measure of linearity control to compensate for valve and component variations.

This method is applicable to the frame scanning circuit although as can be seen from Table 2 a smaller degree of correction is required in this case due to the 4:3 aspect ratio employed.

Table 2

Line Scanning angle	*Frame Scanning angle*
53°	40° 36′
70°	55° 48′
90°	73° 48′

Appendix

To arrive at an expression for angle of deflexion θ for applied flux H in a magnetically deflected cathode-ray tube, let the flux be normal to plane of paper and length of deflexion coil be given as L (Fig. 6).

The force on an electron after it enters a magnetic field is given by:

$$F = H.e.v. \text{ dynes} \quad \ldots\ldots\ldots\ldots \quad (9)$$

and angular velocity ω,

$$\omega = H\,.\,e/m \text{ rads/sec} \quad \ldots\ldots \quad (10)$$

where: H = magnetic flux density

$$e/m = \frac{\text{electron charge}}{\text{electron mass}}$$

v = velocity of electron cms/sec

but: $r\omega = v$

$$\therefore v/r = H\,.\,e/m \quad \ldots\ldots\ldots\ldots\ldots \quad (11)$$

from Fig. 6 $L/r = \sin\theta$

substitution in (11) gives:

$$v/L \sin\theta = H\,.\,e/m$$

$$\text{or } \sin\theta = L/v\,.\,H\,.\,e/m \text{ E.M.U.} \quad \ldots\ldots \quad (12)$$

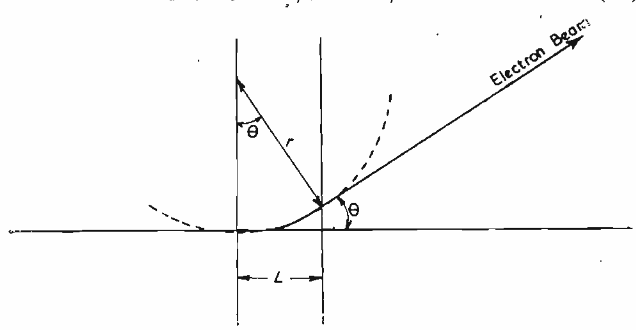


Fig. 6. Derivation of expression for angle of deflexion

The velocity of an electron in terms of applied accelerating potential E is:

$$E\,.\,e = 1/2\; m\,.\,v^2 \quad \ldots\ldots\ldots\ldots\ldots \quad (13)$$

$$\text{giving } v = \sqrt{(2E\,.\,e/w)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (14)$$

substituting in Equation (12) gives:

$$\sin\theta = \frac{HL}{\sqrt{2E}}\,.\,\sqrt{e/m} \quad \ldots\ldots\ldots \quad (15)$$

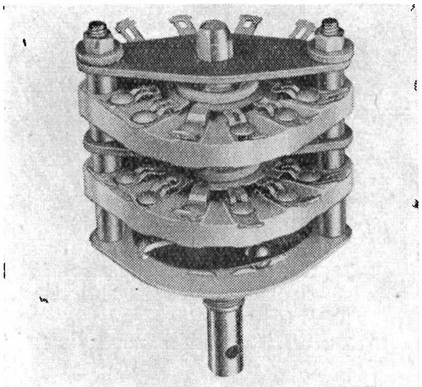
Expressing H in gauss, E in volts, L in cm, and inserting the value of e/m for an electron gives the practical expression:

$$\sin\theta = 0{\cdot}30\; HL/\sqrt{E} \quad \ldots\ldots\ldots\ldots \quad (16)$$

R.E.C.M.F. EXHIBITION PREVIEW

A description of selected exhibits at the Exhibition of the Radio and Electronics Component Manufacturers Federation to be held in the Grand Hall, Grosvenor House, Park Lane, London, W.1. from April 7 - 9.

(*Figures in parenthesis refer to Stand Numbers.*)



A.B. Metal Products, Ltd. (21)

(*Illustrated above*)

A RANGE of rotary switches with ceramic insulation have been developed by A.B. Metal Products, Ltd. The switches are a new version of the Type "H" switch, but with ceramic insulation instead of the normal S.R.B.P. insulation.

The wafers are manufactured from high "K" electrical porcelain, making the switch suitable for circuits where the R.F. characteristics are important.

The surfaces of the wafers are highly glazed to make them completely impervious to moisture when used under tropical conditions.

A.B. Metal Products, Ltd.,
16 Berkeley Street,
London, W.1.

Automatic Coil Winder and Electrical Equipment Co., Ltd.

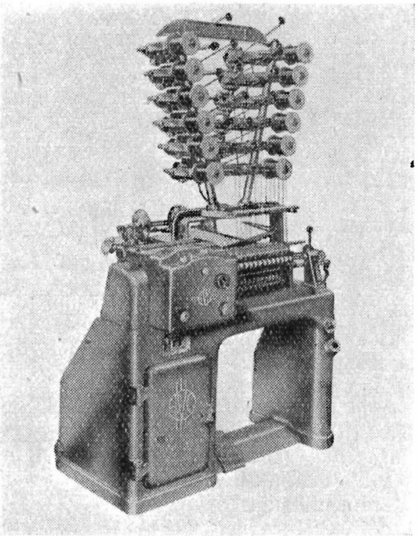
(*Illustrated centre*)

THE Douglas Automatic Multi-Winder is designed for high speed production of large quantities of coils with or without paper interleaving. The machine will wind up to 12 coils simultaneously, for 12 reel carriers are provided, and it is fully automatic in operation.

It winds round, square or rectangular coils ranging from ½in. to 7½in. long, and up to 4½in. diameter, with or without paper insertion. If paper interleaved coils are being wound, formers without cheeks must be used, since the coils are wound in one continuous length. The machine can be supplied in two models, one giving 153 changes to cover the winding of wires from 47 S.W.G. to 30 S.W.G., and the other having a gear box with loose change wheels which will permit the winding of wires from 47 S.W.G. to 26 S.W.G.

The multi-winder is fitted with a variable speed motor and will allow for winding at headstock speeds between 600 R.P.M. and 2,000 R.P.M. The revolution counter is of the five-figure preset type which will automatically stop the machine when the required number of turns have been wound on the coil. If the wire from any one reel carrier should break or the supply wheel run out the machine stops automatically.

The Automatic Coil Winder and
Electrical Equipment Co., Ltd.,
Winder House, Douglas Street,
London, S.W.1.

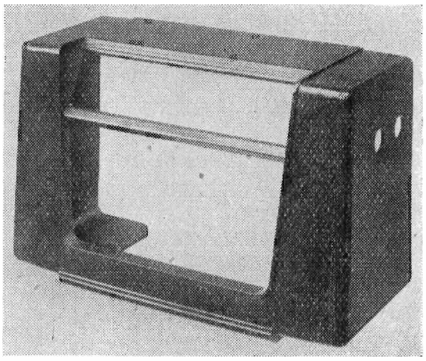


British Insulated Callender's Cables, Ltd. (27)

THE new Mark 3 37-contact moulded-on polypole coupler with a replaceable metal shell will be shown for the first time. It embodies all the features of the Mark 2, but with reduced size and weight and provision for three twin or coaxial and 30 other circuits. Together with associated cable it has been designed for use with both studio television cameras and outside broadcast television units.

Full technical details of the Mark 3 had not been released at the time of going to press.

British Insulated Callender's
Cables, Ltd.,
Surrey House, Embankment,
London, W.C.2.



British Moulded Plastics, Ltd. (102)

ILLUSTRATED above is the new radio cabinet made for Messrs. Regentone Products, Ltd., by British Moulded Plastics, Ltd. It is made from polystyrene material by the injection process on a 50oz. capacity hydraulic press.

The moulding weighs approximately 17oz. The feed is arranged to enter the scale opening, and is removed by blanking after moulding.

British Moulded Plastics, Ltd.,
Avenue Works,
Walthamstow Avenue,
London, E.4.

A. F. Bulgin and Co., Ltd. (39)

AMONG the new Bulgin components are additions to the Pilot lampholder range for conventional screw and bayonet caps, including models of higher tropical resistance suitable for high voltage use to comply with the demand for higher insulation resistance under adverse conditions.

In accordance with safety requirements, temperature sensitive cut-out devices are being introduced, operating over a range of temperatures to assist equipment compliance with the revision of BS.415 proposals. They operate by local temperature, largely independent of current flow, and have wide and high value of rupture capacity.

New safety mains connectors will also be shown which are in accordance with latest specification requirements and recommendations for cable gripping, cable-entry, inter-changeability and rating. Also new micro-switches are making their first appearance, including miniature types, and models for high operational pressure.

A. F. Bulgin and Co., Ltd.,
Bye Pass Road,
Barking, Essex.

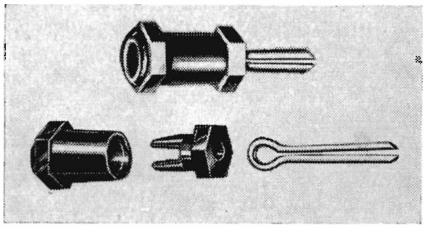
Carr Fastener Co., Ltd. (17)

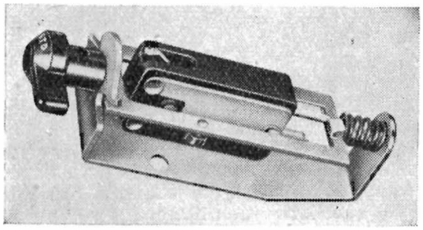
(Shown centre)

THE new "Cinch" wander plugs consist of a strong plastic body and sleeve with a plated split pin, and are designed for ⅛in. diameter sockets. They are available in red or black, and other colours may be had to order.

The feature of this plug is its simplicity in assembly—the flex is threaded and then twisted round the loop of the pin. The sleeve portion of the wander plug is snapped on to the body, completing the assembly.

The Carr Fastener Co., Ltd., Stapleford, Notts.





Cosmocord, Ltd. (25)

(Illustrated above)

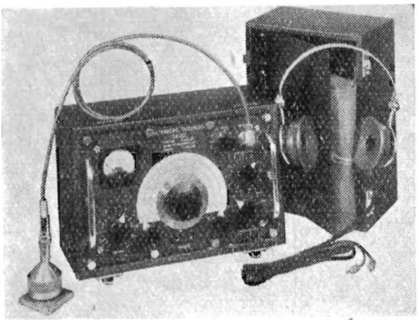
THE Cosmocord "Acos" G.P.29 cartridge is designed to give reproduction of both standard and long-playing records for the usual type of domestic radio receivers.

The output of the cartridge is about 0·7V at 1,000c/s from standard records, and approximately half that from long playing types.

The response characteristics of the two sides of the cartridge are arranged to give optimum performance in both cases. The standard record side gives a falling characteristic beyond 5kc/s, and the bass end is compensated to within about −3db at 70c/s. The result is balanced reproduction suggesting a wide range, but providing little or no needle scratch. Long-playing records with their softer surfaces require no top cut except to compensate for pre-emphasis in recording, and most domestic receivers have enough to compensate for this, so that to give the best overall balance the long-playing output of the cartridge had to be raised above 5,000c/s.

The cartridge takes two sapphire tipped cantilever styli which are held in the needle chuck by a set screw. They are easily replaceable when so required in service. The cartridge is supplied either with two side brackets or mounted in a turnover mechanism.

Cosmocord, Ltd., Enfield, Middx.



Dawe Instruments Ltd. (49)

(Shown bottom left)

THE new Dawe Ultrasonic Thickness Gauge Type 1101 is an apparatus for measuring the thickness of materials by means of high frequency sound waves, and has been specially developed for applications where one surface only is accessible.

The instrument measures thickness from one side by determining the fundamental natural frequency of vibration in the thickness direction, which is essentially independent of the other physical dimensions of the material.

A vibrating quartz crystal is placed in contact with the material under test so that an ultrasonic wave is transmitted into the material. The wave then travels in a narrow beam through the material and is reflected by the opposite surface. At frequencies when the transmitted and reflected waves are in phase, there will be a relatively large increase in the amplitude of the wave in the material. This is a resonance condition occurring at a fundamental frequency which is inversely proportional to twice the thickness and directly proportional to the velocity of sound in the material. Since the velocity of sound is a known constant, the determination of the fundamental frequency required to produce resonance is an accurate gauge of the unknown thickness.

By frequency modulating the electronic oscillator which drives the quartz crystal, a signal is produced at the fundamental frequency and at harmonics of the fundamental frequency. This signal is heard in a set of headphones, and is simultaneously indicated by an increase in the deflexion of a panel milliammeter. The difference in frequency between any two adjacent signals is measured on a scale which is calibrated in frequency. A conversion scale on the instrument panel shows the thickness corresponding to the measured difference.

The gauge has a thickness range of 1/16in. to 12in. of steel, and an accuracy of ±3 per cent provided the working surfaces are clean and flat. Special crystal units can be supplied to improve the accuracy of measurement on curved surfaces. Materials suitable for testing with this gauge are: brass; aluminium; copper; nickel; glass, and some plastic materials.

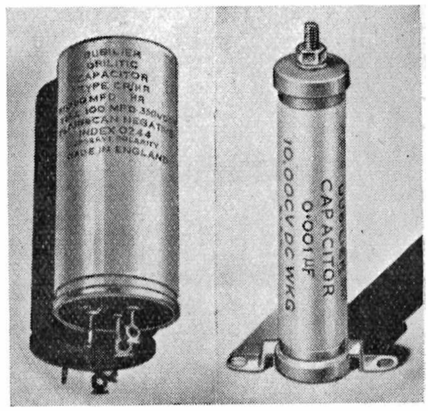
The instrument has a self-contained power supply from dry batteries, and is housed in a metal case which also holds the headphones, crystal unit and other accessories. It weighs 24lb.

The ultrasonic thickness gauge is made under licence from Branson Instruments, Inc. and the General Motors Corporation, of the U.S.A.

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

Dubilier Condenser Co. (1925), Ltd. (50)

ILLUSTRATED below on the right is a Dubilier nitrogol high voltage television capacitor, which is designed for obtaining D.C. from fly-back voltage or H.F. oscillators. The capacitor comprises a high voltage nitrogol processed tubular paper dielectric element, assembled in a glazed ceramic tube. To the platinized ends of this tube are soldered metal and cap terminals to provide hermetic sealing.



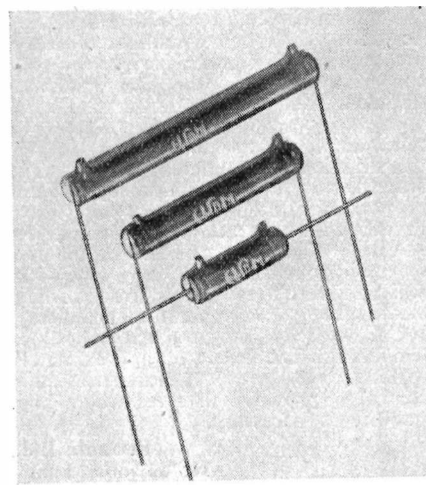
Shown on the left of the same picture is a drilitic electrolytic capacitor with high capacitance and high ripple current sections for use in television circuits. They are available with single and dual capacitor units in a single container, and the construction ensures that the electrolyte cannot contact any other than high purity film forming metal.

Dubilier Condenser Co. (1925), Ltd., Dunon Works, Victoria Road, London, W.3.

Electronic Components, Ltd. (88)

THIS firm are introducing a range of miniature wire-wound vitreous and lacquered resistors which gives complete coverage of the sizes and ratings to the relative R.C.L. Specification.

Provision is made for either radial or axial termination, and these can be altered easily without affecting the overall physical dimension of the resistors,

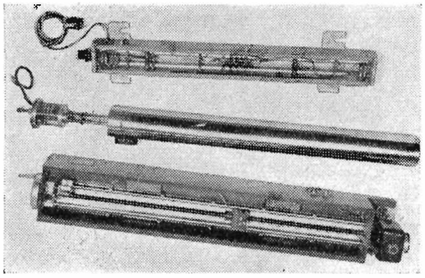


since the radius formed at the bend takes place in the slot, the latter providing extra mechanical support for the wire when used in the radial position.

Silver clad leading out wires are used in these resistors, as they resist oxidization in storage and facilitate the making of soldered joints on installation.

The resistors are available in the range of 1Ω to 200kΩ, with wattages from 5 to 25W. The lengths of the resistors are from ¾in. to 2⅞in.

Electronic Components, Ltd.,
Weedon Road, Industrial Estate,
Northampton.



Ferranti, Ltd. (54)

(Illustrated above)

THE Magnetostriction Delay Line was developed in connexion with the 1,000Mc/s distance measuring equipment which utilizes pairs of pulses as part of the channelling system; the spacing between pulses being critical. The purpose of the line is to generate or detect pulses of a given spacing to a high degree of accuracy.

The line itself consists of a number of strands of nickel wire connected at both ends by a terminal plate. This wire is threaded through small coils called transmitter and receiver coils, the receiver coils having a small bar magnet which produces a steady flux through the coil. When a current pulse is passed through the transmitter coil a constriction in the nickel takes place. This constriction passes along the line at a constant velocity, and when the constriction wave reaches the receiver coil the flux passing through the coil is reduced and a small voltage is generated across the receiver coil terminals. The velocity of propagation of the stress wave is approximately 1cm in 2·08 microseconds, and by spacing the coil at a given distance from the transmitter coil an accurate delay can be produced. Where a number of delays are required, a number of receiver coils can be threaded on the line at various distances from the transmitter coil.

In order to minimize the effect of reflexion at the terminations of the line the strands are of different lengths. The reflexions are thus broken up by a factor proportional to the number of wires used. In these lines 24 strands are employed. A spring is used at one end of the line in order to ensure that it is always in tension and to avoid undue stresses which may result from temperature changes.

The velocity of propagation has a temperature coefficient of approximately 0·015 per cent per °C, and thermostatic control is provided in cases where high stability is necessary.

Ferranti, Ltd.,
Hollinwood, Lancs.

The General Electric Co., Ltd. (104)

A PROTOTYPE of an aluminized circular tube with a 16in. "flat" screen will be exhibited. This tube has a 70 degree angle, and operates on an E.H.T. voltage of 12kV.

Full technical details of this tube had not been released at the time of going to press.

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

Goodmans Industries, Ltd. (35)

(Shown top right)

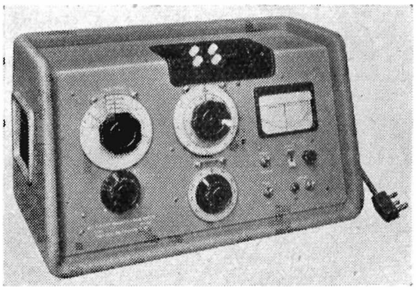
GOODMANS Industrial Vibration Generator has been designed for testing equipment for its ability to withstand mechanical vibration. Our illustration shows a piece of radio equipment under test.

The vibration generator consists of a moving coil armature operating in the field of a large permanent magnet. The neck of the armature terminates in a connecting rod having a ¼in. B.S.F. threaded hole for load fixing purposes. Provision has also been made for forced air cooling, should the need arise.

The moving coil can be driven either by a fixed or variable frequency oscillator or by a 50c/s A.C. mains supply. It has a power handling capacity of 40 watts, but with forced air cooling this can be raised to 120 watts.

The generator has a range of 0-10,000c/s, the acceleration per ampere being 17g unloaded, and the total stroke ½in.

Goodmans Industries, Ltd.,
Axiom Works,
Wembley, Middx.

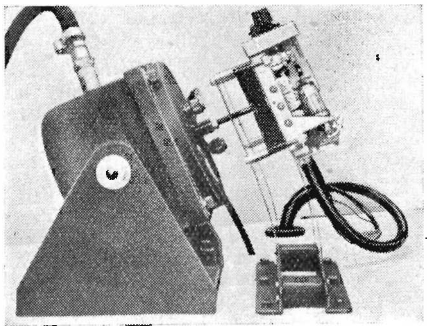


Marconi Instruments, Ltd. (105)

(Illustrated above)

THE Marconi Circuit Magnification Meter Type TF886A is primarily a direct reading Q meter for use in the frequency range 15-170Mc/s; a feature of the design is the use of only one meter for the simultaneous monitoring of the injected and developed E.M.F.'s by a balance method which renders the oscillator level non-critical. The essential controls consist of an oscillator frequency dial, a slow-motion tuning dial for the test circuit and a dial directly calibrated in Q.

The oscillator comprises a single valve which covers the frequency range in four bands, the tuning capacitor being directly calibrated in frequency. The test circuit includes a very low-inductance into which the output from the oscillator is injected in series with the coil under test, tuning being by



means of an internal low-loss capacitor directly calibrated in capacitance, and terminals are provided for the checking of capacitors.

The injected voltage and the voltage developed across the tuned circuit at resonance are rectified by independent diode systems and applied in opposition to a bridge-connected D.C. amplifier with centre-zero balance indicator, balance being obtained by adjusting a variable resistance calibrated directly in Q.

Marconi Instruments, Ltd.,
St. Albans, Herts.

The Micanite and Insulators Co., Ltd. (51)

HIGH Heat Micanite has been developed by this company, and is built-up mica which, owing to the use of an inorganic bond, is self-supporting at temperatures up to 500°C.

High Heat Micanite maintains its electrical properties at high temperatures, and is suitable for unsupported electrical heating elements, surface heaters, all types of resistances and heating elements on voltages up to 600 where the temperature of the micanite does not exceed 500°C.

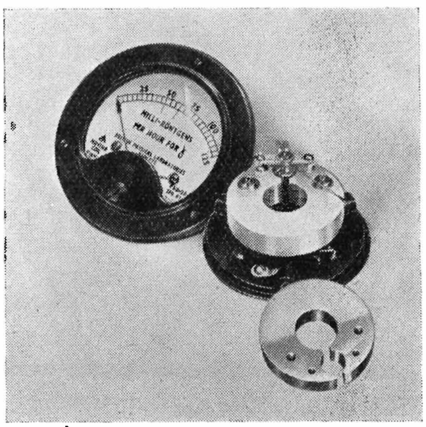
It may be used as an alternative to block mica in many applications, and is available in flat sheets only, in lengths of up to 40in. It is produced in thicknesses up to 0·06in., with a density of 2·4 to 2·5, and to ensure adequate mechanical strength a minimum thickness of 0·02in. is recommended.

The Micanite and Insulators Co., Ltd.,
Empire Works, Blackhorse Lane,
London, E.17.

Murex, Ltd. (76)

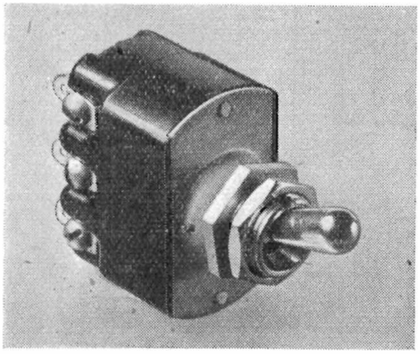
(Shown below)

THE Murex range of small sintered permanent magnets has been extended



to include sintered composite magnets in which the soft iron pole pieces are sintered as an integral unit with the Alnico type of magnetic material which composes the body of the magnet. These magnets have many applications in industrial fields.

Powder Metallurgy Division, Murex Ltd., Rainham, Essex.



Painton and Co., Ltd. (36)

ON display for the first time is a new television/radar plug and socket. This incorporates two co-axial units (Post Office type) and twelve contacts as used on the normal range of Painton plugs and sockets. This composite plug and socket enables complete supplies (vision/power/etc.) to be made to panels or chassis, replacing the need for many plugs and sockets as previously required. A new design of cable clamp is incorporated in the composite plug.

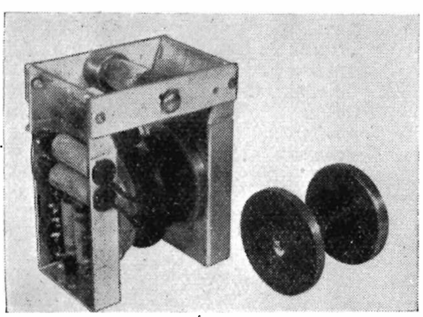
Illustrated above is an addition to the Painton range of toggle switches—a double-pole-changeover switch for 6-amp 250 volts A.C./D.C. operation. Spring-loaded shrouded and unshrouded terminals suitable for mains voltages constitute another new item. These are available with various coloured markings as required.

Painton and Co., Ltd., Kingsthorpe, Northampton.

The Plessey Co., Ltd. (42)

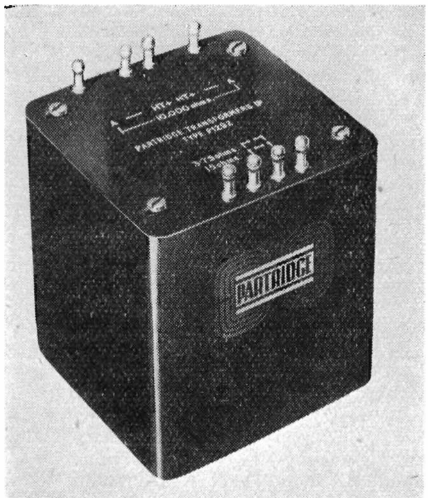
A RANGE of television components, designed to meet the conditions imposed by the new "wide-angle" cathode-ray tube development will be shown. Many of the components utilize the television grade of "Caslam" core material, which has a high electrical performance. Illustrated below is a wide angle type 14kV line transformer and a "Caslam" core.

The use of "Caslam" core material enables robust and mechanically accurate



deflexion coil assemblies to be manufactured with improved electrical performance, higher deflexion sensitivity and higher Q value, complete designs of which are available for cathode-ray tubes of 55°, 65° and 70° scanning angles. For narrow angle tubes, two coil designs are available. A split cylindrical core is used for a 2¼in. long coil, giving high deflector sensitivity where neck shadowing is not a serious problem. A shaped core block designed to give higher magnetic efficiency is utilized in a shorter 2in. coil, reducing shadowing difficulties without significant loss of sensitivity. For wide angle tubes of 38·5mm. neck diameter, a choice of coil assemblies is available. For the wide angle tube of 35mm. neck, a coil design is available based on the "Caslam" block used for the 2in. coil.

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



Partridge Transformers, Ltd. (55)

(Illustrated above)

PARTRIDGE are introducing a range of push-pull output transformers is intended for use in equipment reproducing the full audio-frequency range with low distortion. The characteristics are such that these transformers can be used in circuits when considerable feedback is taken from the secondary winding and injected into a point three or four stages back.

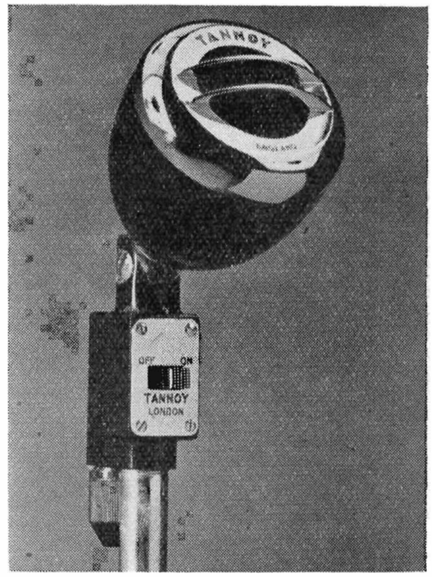
The transformers have a power rating of 16 watts for less than 1 per cent distortion maximum D.C. per half primary 60mA, and an anode to anode load of 10,000Ω, with a permissible D.C. unbalance of 20 per cent. The leakage inductance measured as a series element in the primary is 10 to 15mH, and the self-capacitance 680pF per half primary. The shunt inductance of the primary is 85H at 5V 50c/s, and 145H at 30V 50c/s, and the D.C. resistance of primary windings is 150Ω per half winding.

Partridge Transformers, Ltd., Roebuck Road, Tolworth, Surrey.

Tannoy Products, Ltd. (40)

(Shown top right)

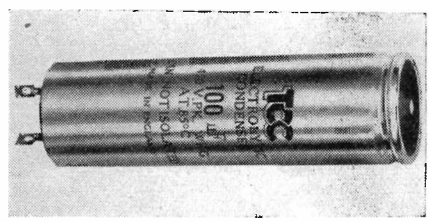
THE moving coil microphone type MC.424 has a linearity of frequency response of ±3db from 30 to



12,000c/s. It has a high sensitivity of −76db below 1V in a sound field of 1 dyne per square inch, and this factor, combined with the linearity of frequency response, makes it suitable for installations where fidelity of reproduction is required. The polar response is non-directional up to 3,000 cycles per second, there being some attenuation from the rear at frequencies higher than this. The microphone has an impedance of 600 ohms, and is supplied with a Tannoy plug and 20ft lead.

The microphone performance is stable, being unaffected by conditions of temperature, humidity, etc. It is also unaffected by wind disturbances, etc., which makes it very suitable for high quality open air installation.

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



The Telegraph Condenser Co., Ltd. (34)

T.C.C. are introducing a range of high temperature electrolytic capacitors which are able to work at 85°C without voltage derating.

The capacitors have a low leakage current at room temperature, with only a minor increase when the temperature is raised, and a long shelf life. Because of their high working temperature and low leakage current they handle higher ripple currents for the same size of case.

Illustrated is one of the larger types, but they are also available in a full scale of values and voltages in similar appearance to the T.C.C. Micropack and Picopack designs.

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

BOOK REVIEWS

Cathode Ray Oscillographs

By J. H. Reyner. 4th Edition. 199 pp., 138 figs. Sir Isaac Pitman and Sons Ltd. November, 1951. Price 15s.

AT first sight this book seems very small for its price, but it is a neat and workmanlike volume containing a large amount of information. The standard chosen is not very advanced, but is mostly up to date and suitable for those who wish to know something about the subject in a general way. It is almost completely non-mathematical.

After a brief description of various cathode-ray tubes in Chapter 1, there follows a chapter containing some fundamental facts about electrostatic and electromagnetic deflexion, and the production of images of various waveforms. On page 1 it states ". . . the cathode ray tube provides facilities for moving the spot in two directions at once . . . ," but fortunately the formation of a visual waveform is made clear later on. Simple power supplies are shown, and a number of possible troubles such as origin and trapezium distortion, deflexion by stray magnetic fields, and brightness modulation due to ripple voltages are discussed, illustrated, and the cures described. Incorrect work amplitude and time-base speeds are also shown by means of photographs. Throughout the book there are a great number of informative photographs of C.R.T. traces.

On page 45 there appears an incorrect explanation of the self-centring action of an A.C. coupled C.R.T. The author says, that ". . . the application of a steady voltage to the deflecting system will cause the spot to take up its displaced position, and at the same time the isolating condenser will acquire a charge. This charge, however, will gradually leak away through the high resistance leak so that the spot will gradually drift back to its original position." He goes on to say that ". . . the discharge is exactly the inverse of the charging of the condenser previously discussed." After stressing the importance of a long time-constant in the coupling, the author says that ". . . even such a time constant would be quite inadequate to keep the spot permanently deflected indefinitely." Untidy sentences such as this and incorrect explanations are particularly out of place in a book of this nature.

Waveform examination, time-bases and Y amplifiers are discussed and their limitations and use described in Chapter 3.

Another of the misleading explanations appears on page 74 in the description of what is called a "Single Valve Push-Pull Time Base Amplifier" showing a tetrode with push-pull outputs coming from loads in the screen and anode. The author explains that the anode and screen currents are complementary so that an increase of anode current is accompanied by a decrease in screen current. This is not so if the input into g_1 is as shown in Fig. 54.

Hard valve time-bases are also mentioned briefly, although the author states that thyratrons are the discharge devices most commonly employed. This is not true now, nor has it been for some years past.

Chapter 4, dealing with deflexion amplifiers in some detail, is interesting and well illustrated.

Chapter 5 is about frequency response curves and their formation, and Chapter 6 covers valve characteristic and *BH* curves.

The elements of frequency comparison by means of Lissajous figures and double beam C.R.TS. are explained in Chapter 7, which is also very well illustrated. The circuit of a standard frequency generator consisting of a crystal oscillator and dividers is given and typical waveforms are shown.

In Chapter 8 the examination of modulated and unmodulated R.F. waveforms and the appearance of amplitude distortion, phase shift and asymmetrical modulation are illustrated and described.

The difficulties of amplifying very low frequencies, the troubles of D.C. amplifiers and modern circuits which overcome some of these difficulties are covered in Chapter 9. The treatment is quite brief, and it is a pity that there are so few references to other works on this subject as it is of very great importance. In fact it is a pity that there are so few references in each of the chapters. They could be so helpful to readers who would like more detailed information.

Various special time-bases, single sweep, circular, zig-zag and so on, are shown in Chapter 10 and their uses described. A circuit is shown for a single sweep time-base triggered by a transient A relay is used to keep a capacitor discharged and the transient itself is shown as operating the relay to initiate the scan. The transient is also delayed and then applied to the Y plates of the C.R.T. The author says that ". . . a length of cable is sometimes used for this purpose." Surely it would need quite a length of cable, even special cable, to delay the signal for enough time, at least a millisecond, to allow the relay to operate. If the circuit is meant to show the principle only, then this should be made quite clear in the text. Cable is shown on the diagram. Delay lines using lumped circuits are mentioned, and one of the few references to other works is given for further, more detailed, information.

The book ends with some useful information about photography of cathode-ray tube traces and a brief mention of circuits such as electronic beam switches, engine indicators and a few others. For some reason a description of a capacitance micrometer circuit, having no connexion with the title of the book, has been included in this chapter.

The book is presumably written for, and should be useful to, students and others who wish to know about the techniques of using C.R.T. oscillographs. It is generally well presented and extremely well illustrated. The reviewer thinks it is a pity that, with very few exceptions, no component values are given in the circuits, and it would have been useful to many beginners if a few complete circuits, such as time-bases and amplifiers, were included. It is also very unfortunate that misleading or incorrect explanations of circuit operations are given. An inexperienced student might well be upset when, after setting up a circuit such as the electronic sweep circuit, Fig. 88, page 129, he finds that instead of a D.C. output proportional to the input frequency, as the text explains, he obtains a sine wave which is D.C. restored to earth, not by any means the same thing, to apply to the X plates of his C.R.T.

C. H. BANTHORPE

Vacuum Physics

A Symposium of the Midland Branch of the Institute of Physics. 80 pp. The Institute of Physics. December, 1951. Price 15s.

THE Institute of Physics is to be complimented on its publication of this first supplement to *The Journal of Scientific Instruments.* High vacuum equipment is rapidly becoming quite commonplace in all laboratories, and this collection of papers should serve a useful purpose in bringing to the notice of specialized workers the apparatus and methods used by others.

The supplement is a little tardy in publication—over one year since the Symposium was held. The text is clear and well supported with diagrams which occur on the pages where reference is made to them, thus obviating tiresome hunting. Nine pages are devoted to a comprehensive subject index, and as sixty-eight pages are given over to the text no difficulty should be experienced in locating any required information. The name index refers to well over two hundred authors.

Most of the papers deal briefly with the subject given as the title and consist of some repetition of previously published work. Mr. D. R. Goddard discusses vacuum pumps on conventional lines in the first paper. Mr. T. S. Miller's paper on "The Design of Industrial Vacuum Systems" covers the subject well, but possibly could have been expanded with some details of actual performances. To Mr. W. Stechelmacher fell the rather much publicized subject of gauges. He acquitted himself very ably and provides an excellent list of references to parallel publications. The paper on the general principles of leak detection by Messrs. J. Blears and J. H. Leck will be of interest to workers concerned with vacuum plant. The discussion following this paper also contains much useful information. The construction and operation of a cold-cathode mass spectrometer leak detector have been very fully dealt with by Mr. C. J. Milner. The references and discussion given to this instrument are most interesting when read in conjunction with the next paper on the application of the mass spectrometer to high vacuum problems.

A truly industrial application of vacuum processing is described by Mr. D. R. Goddard in "Large Scale Vacuum

Dehydration," while laboratory or research use is handled by Dr. R. Riddiford of Birmingham University. This latter paper entitled "The Vacuum System of the Birmingham Proton Synchroton" is the most comprehensive of this collection. Several diagrams and photographs give some idea of the physical size and difficulties of the project. Physicists and engineers who are perhaps used to what one might describe as "an under the bench" vacuum equipment will appreciate the effort, skill and co-operation necessary for such apparatus, and the amount of useful practical information contained in this report.

The final three papers (abbreviated in publication) deal with apparatus in which the vacuum equipment is used only as a tool. "Recent Advances in Vacuum Coating Plant and Techniques" by Mr. L. Holland deals with such topics as lens blooming and the metallizing of plastic foils and cathode-ray tube screens. Metallurgists as well as vacuum physicists will be interested in Mr. E. D. Malcom's paper on "Melting and Sintering of Metals in Vacuum." The final contribution is entitled "Freeze Drying—Vacuum Sublimation" by Mr. L. G. Beckett, and describes equipment used for the dehydration of heat sensitive materials by sublimation from the frozen state.

The whole collection makes very interesting reading, and even a casual perusal will be of value to anyone involved in low pressure techniques.

T. A. J. JAQUES

T/V Master Antenna Systems

By Ira Kamen and Richard H. Dorf. 368 pp., 234 figs. John F. Rider Publisher Inc., New York. 1951. Price $5.00.

T/V master antenna systems, or communal aerial systems as they are more usually referred to in this country, are increasing in importance with the rapid growth of television both here and in America, but they have so far received somewhat less attention than they deserve. As more and more television aerials spring up on the roof tops it becomes abundantly clear that some solution must be applied before long to limit their ever-increasing numbers. For densely populated areas such as blocks of flats and hotels where the problem is even more pressing, such a solution is provided by the communal aerial system, by means of which a considerable number of receivers can be fed from one centrally sited aerial array.

This book makes a valuable and timely contribution to a subject, on which there has so far been very little published information. It opens with a chapter describing basic aerial types, transmission lines, and receiver front end design, followed by a well reasoned chapter on the need for communal aerial systems. The bulk of the book is then devoted to detailed descriptions of practically every commercial amplified and non-amplified system available in the American market. There are further chapters giving practical information on the installation of systems, and commercial arrangements with property owners, architects, etc., together with a short chapter dealing with video frequency distribution systems for special applications.

Although the authors have provided a considerable amount of technical detail, they have presented it in such a way that it will prove informative to the prospective user, as well as to those who may be planning and installing systems, and this presentation has been further facilitated by the numerous illustrations. Many of the systems described are not representative of normal practice in this country, since the complexity of both the amplifier equipment and the aerials is necessarily increased by the need to cater for reception of a large number of channels simultaneously, but nevertheless the general principles governing the design of communal aerial systems are adequately presented.

This book is recommended not only to those who are concerned with the provision and maintenance of communal aerial systems, but also to others who are interested in television reception and distribution, and to whom such systems as a method of distribution are a little-known art.

K. J. EASTON.

Autobiography of Robert A. Millikan

By R. A. Millikan. 334 pp. Macdonald and Co., London. October 1951. Price 21s.

PROFESSOR MILLIKAN gives a straightforward and very readable account of his life's work in physics and its applications. American physics was in an extremely backward state, compared with European, when he started his career in physics, more or less by accident, in 1886; as this book shows, he has been in the forefront of the phenomenal development which has occurred since then. One admires his single-mindedness; throughout his career not only has he been firmly wedded to the academic life—among the industrial offers he declined was that of the directorship of the Westinghouse Research Laboratories—but he has insisted on following the particular kind of academic life he wanted, and he refused several professorships before he was finally appointed professor at Chicago in 1910, at the age of 42.

Millikan's name will go down to posterity for his oil-drop measurements of the charge on the electron, and pioneer work in other branches of physics. But he regarded his teaching as being as important as his own researches; and he found time to develop strong convictions on what he regarded as America's responsibilities in world politics. He thought America should have been in the First World War from the beginning; and when she did at last come in he threw himself whole-heartedly into the scientific war-effort. Afterwards he was greatly disappointed by America's attitude to the League of Nations.

The book ends with a chapter setting out his conclusions on the relationship between science and religion; he finds no justification for the conflict which he considers still exists, but his view of religion is, to the reviewer, so naive that this is not surprising.

D. H. FOLLETT

Letters to the Editor

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

Input Balance Control for Biological Amplifier

DEAR SIR,—A simple and effective manual control for reducing or eliminating unwanted pick-up in a biological amplifier has been in use by the writer for some years. Since the method, although simple, has not been described previously, a brief note may be of value. In many published circuits of pre-amplifiers (e.g., Dickinson,[1] 1950), a balance control in the form of a potentiometer in the H.T. supply to the first stage is shown. I have not found this very effective, and instead have resorted to the use of a high-resistance potentiometer (R_1) across the input terminals, with its slider earthed (Fig. 1). A value of 2 to 5MΩ is suitable. Since no grid current flows through R_1, it can be adjusted at any time without causing more than a slight disturbance of the output baseline. With leads connected to the electrodes and the animal preparation earthed, the control is rotated until a sharp null or minimum of the interference wave is attained. For most forms of interference the control is highly effective. The mode of action of the control is obvious when the connexions to the animal are considered. The "balanced" amplifier gives a very small output for in-phase input signals, when these appear in equal amplitude at the input grids. The earthing of the preparation is necessarily an arbitrary procedure, so that in-phase potentials, as e_p, e^1_p which appear between

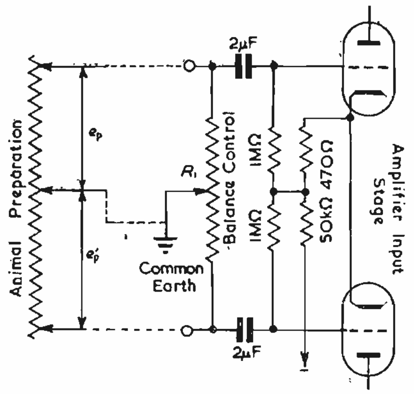


Fig. 1. Input Balance Control for Biological Amplifier

each lead and earth, may exhibit asymmetry over a wide range. By means of R_1 the inputs to the amplifier grids are then adjusted to equality by varying the "ratio arms" of R_1. The control is then effective, whatever the electrical situation of the earth on the preparation. Such a control evidently is also effective in dealing with expected slight imbalance of the input stage valves, in that the in-phase input voltages may be adjusted to a suitable asymmetry with respect to earth to compensate for such imbalance.

Finally, such a control does not entirely eliminate the necessity for screening, in situations where interference levels are high. Especially when dealing with large preparations, considerable anti-phase interference pick-up may occur, against which no balancing method will prevail. The control could, of course, not be used with a high gain D.C. amplifier, because of noise considerations arising out of grid current flow.

Yours faithfully,

W. H. CATTON,

Medical School, King's College,
Newcastle-upon-Tyne.

REFERENCE

[1] Dickinson, C. J., Electrophysiological Technique. (Electronic Engineering Monograph, 1950.)

The Optical Projection Comparator

DEAR SIR,—The Optical Projection Comparator described by Mr. Gold in the January issue appears to be somewhat limited in its practical application. The advantages of using standard 16mm. equipment to minimize cost are rather outweighed by the relative complexity of the system and the fact that it occupies a considerable volume. Further, the rapid and accurate comparison of two traces alongside one another without the aid of a mirror system is not easy.

For laboratory purposes a series of transparencies which may be clipped in front of the cathode-ray tube screen are very cheap and easily made. A simple form consists of thin acetate (or other transparent) sheet on which the trace and instructions are drawn with indian ink and a second sheet mounted against the first to protect the ink. For purposes where loose pieces are a disadvantage, the comparison trace may be recorded photographically or in ink on thin acetate sheet mounted similarly to the roll film in a camera.

A turret system which moves the transparencies directly in front of the screen simplifies the ganging of the associated switch but, even with a small monitor tube, is extravagant in panel space.

It is impossible to generalize on this subject as the justifiable complexity of the monitoring system is a complex function of the purpose of the main equipment, the seriousness of a failure and the skill of the operator.

Yours faithfully,

DOUGLAS S. GORDON,

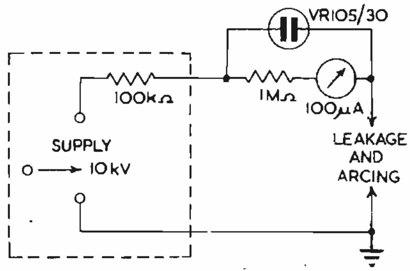
Electrical Engineering Department,
The University, Glasgow, W.2.

A Method of Protecting Current Meters

DEAR SIR.—When measuring the current supplied by a high voltage source it is not always possible to include sufficient series resistance to protect the meter in case of flash over or other current surge. Overload relays are not sufficiently quick in action and fuses are a "once only" protection, both are very difficult to operate at high voltages.

A simple protection consists of a resistor in series with the micro-ammeter or other meter and a neon valve is parallel with both. The resistance is of such a value that when the current rises to say 150 per cent of the meter full scale the neon valve strikes and shunts the excess current past the meter. If and when the current falls the neon will extinguish and the meter return to normal functioning. Normal overload protection should operate after a slight delay if the high current is continued.

The above method may, for example, be used when measuring the corona current on electrostatic precipitators where



the flash-over current is kept high to burn out any particles causing a short and may be many times the meter full scale current. The limit of peak current occurs when the neon starts arcing and damage occurs to the valve, this limit is several times normal current for short times.

A typical circuit is shown above in which the meter reads a normal current of 0-100 microamp while the flashover current can rise to 100 milliamp. The type of neon valve indicated is capable of handling surges of 0·5A.

Yours faithfully,

T. E. BURNUP.

John Logie Baird

DEAR SIR,—I read with interest that a Commemorative Plaque was recently erected to the memory of John Logie Baird, by the L.C.C. on the front of 22 Frith Street, Soho. Frith Street may have been the scene of his first public demonstration but it was at Hastings his first transmission took place. When Baird transmitted an object from one room to another in his Queen's Avenue rooms he got so excited that he rushed out of the front door and collared the first passerby, a somewhat apprehensive young man. The latter doubtfully acceded to Baird's earnest request that he should accompany him inside. Baird sat him down in the appropriate position, switched on and rushed into the other room. To his intense disappointment no face appeared on the screen. He went back again to find that there was a very good reason for this. The young man, evidently thinking that he had to cope with somebody who was not quite "all there" had started to beat a strategic retreat down the stairs. Baird stopped him, and in a calmer frame of mind told him what it was all about. He thereupon returned and sat down again. This time the transmission was successfully accomplished—the first human being to be televised.

Yours faithfully,

W. H. DYER,

The County Borough of Hastings.

Notes from the Industry

The Physical Society's 36th Annual Exhibition of Scientific Instruments and Apparatus will be held from Thursday, April 3 to Tuesday, April 8, excluding Sunday. As in 1951 the Exhibition will be located in both the Royal College of Science, Imperial Institute Road, and the Huxley Building, Exhibition Road, London, S.W.7. Tickets will be valid for entry into both buildings, but on April 3 the Exhibition will be open only to Members of the Society and the Press.

Discourses will be delivered by eminent scientists on Friday, April 4 and Monday, April 7, and the prize-winning entries of the Society's Craftsmanship and Draughtsmanship Competition will be on show. This competition is assuming increasing popularity and importance among instrument making firms, and is another example of the service the Physical Society is undertaking in the national interest.

The Handbook of the Exhibition containing a description of exhibits is available from the Physical Society, price 7s. 3d. including postage.

I.E.E. Summer Meeting in Ireland. The Institution of Electrical Engineers will be holding this summer a meeting in Ireland, centred around Dublin, from June 25 to 28 inclusive. Further details will be announced later.

The 19th National Radio Show. The Radio Industry Council announces that the 19th National Radio Show will be held at Earls Court, London, S.W.5, from Tuesday, August 26 to Saturday, September 6.

Mond Nickel Fellowships. The Mond Nickel Fellowships Committee now invites applications for the award of Mond Nickel Fellowships for 1952. The main object of these Fellowships is to enable selected applicants of British nationality, educated to university degree or equivalent standard, to obtain additional training and wider experience in industrial establishments, at home or abroad, so that, if they are subsequently employed in executive or administrative positions in the British metallurgical industries, they will be better qualified to appreciate the technological significance of research and to apply its results.

There are no age limits, though awards will seldom be made to persons over 35 years of age. Each Fellowship will occupy one full working year. It is hoped to award five Fellowships each year of an average value of £750 each.

Applicants will be required to define the programme of training in respect of which they are applying for an award, as well as particulars of their education, qualifications and previous career. Full particulars and forms of application can be obtained from the Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1. Completed application forms will be required to reach the Secretary of the Committee not later than June 1, 1952.

The University of Birmingham Summer School of Electronics will be held from July 14 to July 19 inclusive, and will cover the fundamental characteristics of electronic apparatus. The lectures are intended to show how far engineering problems are circumscribed by physical laws. Various electronic devices have been grouped into a series of topics, and as far as possible, each topic will be opened with a general theoretical lecture, after which there will be contributions on particular practical applications. The course is intended for engineers and others of university degree or similar standard in electrical technology who have some general knowledge of electronics.

The fee for the course is £2, and early application is advised as the total number attending the course will be limited. Resident students can be accommodated at the Centre for Continued Studies for 15s. a night, including breakfast and evening meal. Both resident and non-resident students can obtain lunch and tea at the University Refectory at a charge of approximately 4s. 6d. a day. Application for enrolment should be made to the Director of Extra-Mural Studies, The University, Edmund Street, Birmingham 3, from whom further information is also available.

Applications of Communication Theory. During September 1950 the subject of information theory was discussed at a symposium held at the Royal Society. Arrangements are now being made for a further symposium, dealing with applications of this theory in the field of telecommunications, to be held at the Institution of Electrical Engineers during the week commencing Monday, September 22, 1952. A preliminary programme of papers to be presented has been prepared and offers of additional papers from both this country and abroad will be welcomed. Copies of the preliminary programme may be obtained by prospective authors and those who may wish to attend the meeting, from Professor Willis Jackson, Electrical Engineering Department, Imperial College, London, S.W.7.

Radio Industry Appointments. Mr. G. Darnley Smith has been elected chairman of the Radio Industry Council in succession to Mr. J. W. Ridgeway, O.B.E. Mr. Darnley Smith has been chairman of the Industry Television Policy Committee since its formation in 1948. Mr. G. A. Marriott, B.A., was elected vice-chairman of the R.I.C.

Mr. P. H. Spagnoletti, B.A., M.I.E.E., and Mr. E. K. Balcombe were re-elected chairman and vice-chairman of the British Radio Equipment Manufacturers Association, which is a constituent association of the R.I.C. At the annual general meeting of the Association recently Mr. Spagnoletti said that 590,000 British receivers and chassis were exported in 1951, which was an all-time record.

PUBLICATIONS RECEIVED

INDUSTRIAL DIAMOND TRADE NAMES INDEX FOR 1951-1952 is a thoroughly revised issue of the last edition, and lists approximately 1,500 trade names of manufacturers of diamond tools, abrasives, etc. It was compiled by the Industrial Diamond Information Bureau and the Industrial Diamond Review. It is available, price 3s. 6d., from the Diamond Research Department, St. Andrew's House, 32-34 Holborn Viaduct, London, E.C.1.

IN THE SERVICE OF INDUSTRY is a fully illustrated, wire-bound booklet produced by the Industrial Group of Philips Electrical Ltd., Century House, Shaftesbury Avenue, London, W.C.2, designed to show the help they have given to diverse branches of industry, and outline the way in which they can aid and advance modern industry by more economical or efficient methods of production. Subjects covered include: the industrial application showroom, electronic measuring instruments, arc welding, resistance welding, motronic control, rectification, magnetic filtration, etc. Free copies are available from the Industrial Group at the above address.

THERMIONIC PRODUCTS LTD. CATALOGUE gives details of the range of instruments which they are now distributing in this country for Bruel and Kjaer, of Copenhagen. The range includes the following: beat-frequency oscillators; deviation test bridges; vibration pick-up and integration networks; voltmeters; level recorders; microphone amplifiers; standing-wave apparatus, and frequency response tracers, etc. Thermionic Products Ltd., Hythe, Southampton, Hants.

THE PHYSICAL PROPERTIES OF THE NICKEL-IRON ALLOYS gives data on the tensile strength, hardness and electrical resistance of the binary alloys and the elastic and expansion properties of both the binary and the more complex alloys. A section dealing with the applications of the alloys outlines their use for a variety of temperature-control devices, for expansion-control in engineering components and for glass-to-metal seals. Copies are available from the Mond Nickel Co. Ltd., Sunderland House, Curzon Street, London, W.1, free of charge.

ELECTRICAL CONTACT MATERIALS is a revised data sheet issued by Johnson, Matthey and Co., Ltd., 73-83 Hatton Garden, London, E.C.1. It describes briefly the characteristics of the company's range of contact materials, and gives recommendations for their usage. It also includes a list of their physical properties.

UNICORN HEAD FILM STRIPS is a new leaflet listing the Unicorn Head educational films now available, and includes nine on electronic subjects. There are six films on the radio valve, two on the cathode-ray tube, and one on the story of radio. They are suitable for technical college audiences. Unicorn Head Visual Aids Ltd., Broadway Chambers, 40 The Broadway, London, S.W.1.

WIRING REGULATIONS FOR SMALL DWELLINGS is an abridged version of the Basic Safety Regulations and Code of Practical Interpretation containing the requirements necessary for single-family dwellings using single-phase A.C. supply. It is abridged from the 12th edition of the Regulations laid down by the Institution of Electrical Engineers, and copies are available from the I.E.E., Savoy Place, London, W.C.2, price 2s. 6d. The full version is also available, price 5s., paper covers, or 7s. 6d., cloth bound.

MODERN PORTABLE ELECTRICITY is a booklet produced by the Ever Ready Co. (Great Britain) Ltd. as a guide on primary cells and batteries for lecturers and teachers in schools and technical colleges. The information it contains has been compiled by the firm's chemists, and the brochure is attractively presented in simple language. Copies may be obtained from Era Publicity Ltd., 7 Fitzroy Square, London, W.1, price 1s. each.

Erratum. We regret that on page 137 of the March, 1952 issue the weight of the Amplivox Miniature Magnetic Earphone was given as $\frac{1}{2}$oz. This should have been $\frac{1}{3}$oz.

MEETINGS THIS MONTH

BRITISH INSTITUTION OF RADIO ENGINEERS

Date: April 3. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.
Discussion: V.H.F. and U.H.F. Broadcasting.
Opened by: Paul Adorian, M.Brit.I.R.E.

Date: April 16. Time: 6.30 p.m.
Held at: London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, W.C.1.
Lecture: Current Radio Interference Problems.
By: E. M. Lee.

North Eastern Section

Date: April 9. Time: 6 p.m.
Held at: Neville Hall, Westgate Street, Newcastle-upon-Tyne.
Lecture: V.H.F. Broadcasting: the Case for Amplitude Modulation.
By: J. R. Brinkley.

Scottish Section

Date: April 10. Time: 7 p.m.
Held at: The Metropolitan-Vickers Works, Motherwell, Glasgow.
Lecture: X-ray Equipment and its Control Gear.
By: C. F. Norton.

South Midlands Section

Date: April 17. Time: 7.15 p.m.
Held at: the Exhibition Galleries, Public Library, Rugby.
Lecture: Acoustics and the Radio Engineer.
By: E. G. Richardson, B.A., Ph.D., D.Sc.

North Western Section

Date: April 30. Time: 7.15 p.m.
Held at: Reynolds Hall, College of Technology, Manchester.
Lecture: V.H.F. Broadcasting: the Case for Amplitude Modulation.
By: J. R. Brinkley.

BRITISH SOUND RECORDING ASSOCIATION

Date: April 18. Time: 7 p.m.
Held at: the Royal Society of Arts, John Adam Street, W.C.2.
Debate: Fact and Fancy—the Modern Gramophone Record.

THE INSTITUTE OF PHYSICS

Education Group

Date: April 17, 18 and 19.
Held at: the Institute of Physics, 47 Belgrave Square, London, S.W.1.
Conference: School and University Examinations in Physics.

Industrial Spectroscopy Group

Date: April 25. Time: 5.30 p.m.
Held at: the Institute of Physics.
Lecture: Impressions of Spectroscopy in the U.S.A.

X-ray Analysis Group

Date: April 3 and 4.
Held at: Edinburgh.
Conference.

THE INSTITUTION OF ELECTRICAL ENGINEERS

Unless otherwise stated, all London meetings take place at the I.E.E., Savoy Place, London, W.C.2, commencing at 5.30 p.m.

Date: April 24.
The Forty-Third Kelvin Lecture: Iron Atoms in the Service of the Electrical Engineer.
By: Sir Charles Goodeve, O.B.E., D.Sc., F.R.S.

Radio Section

Date: April 9.
Symposium of papers on Microwave Links.
Date: April 28 to May 3.
Convention: The British Contribution to Television.

Measurements Section

Date: April 1.
Discussion: The Specification and Measurement of Performance in Servo Systems.
Opened by: Professor A. Tustin, M.Sc., and J. F. Coales, O.B.E., M.A.

Date: April 22.
Lecture: An Analogue Computor for Use in the Design of Servo Systems.
By: E. E. Ward.
Lecture: The Design and Testing of an Electronic Servo-Simulator for a Hydraulic Remote Position-Controller.
By: F. J. U. Ritson, B.Sc. and P. H. Hammond, B.Sc.

Cambridge Radio Group

Date: April 1. Time: 8.15 p.m.
Held at: the Cavendish Laboratory, Cambridge.
Lecture: Radio Astronomy.
By: K. E. Machin, M.A.

Mersey and North Wales Centre

Date: April 3. Time 6.30 p.m.
Held at: the Liverpool Royal Institution, Colquitt Street, Liverpool.
Discussion: Should Broadcasting be Superseded by Wire Distribution ?
Opened by: P. P. Eckersley.

Tees-side Sub-Centre

Date: April 2. Time: 6.30 p.m.
Held at: the Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough.
Lecture: Electricity in Newspaper Printing.
By: A. T. Robertson.

North Midland Centre

Date: April 1. Time: 6.30 p.m.
Held at: 1 Whitehall Road, Leeds, 1.
Lecture: The Sutton Coldfield Television Broadcasting Station.
By: P. A. T. Bevan, B.Sc. and H. Page, M.Sc.

North Midland Utilization Group

Date: April 22. Time: 6.30 p,m,
Held at: the Lighting Service Bureau, 24 Aire Street, Leeds, 1.
Lecture: The Economic Basis of Battery-Electric Road-Vehicle Operation and Manufacture.
By: H. W. Heyman, B.Sc.

North Western Centre

Date: April 1. Time: 6.15 p.m.
Held at: the Engineers' Club, Albert Square, Manchester.
Lecture: Domestic Electrical Installations: Some Safety Aspects.
By: H. W. Swann, O.B.E.

North-Western Radio Group

Date: April 2. Time: 6.15 p.m.
Held at: the Engineers' Club, Albert Square, Manchester.
Lecture: High-Gain D.C. Amplifiers.
By: W. Kandiah and D. E. Brown.

Northern Ireland Centre

Date: April 8. Time: 6.45 p.m.
Held at: the Presbyterian Hostel, Howard Street, Belfast.
Lecture: Some Notes on Electrical Installations in Large Chemical Factories.
By: D. B. Hogg, M.B.E.

Scottish Section

Date: April 22. Time: 7 p.m.
Held at: the Royal Technical College, Glasgow.
Faraday Lecture: Sound Recording—Home, Professional, Industrial and Scientific Applications.
By: G. F. Dutton, Ph.D., B.Sc (Eng.).

North-East Scotland Sub-Centre

Date: April 24. Time: 7.30 p.m.
Held at: the Music Hall, Aberdeen.
Faraday Lecture: Sound Recording—Home, Professional, Industrial and Scientific Applications.
By: G. F. Dutton, Ph.D., B.Sc.(Eng.).

South Midland Centre

Date: April 7. Time: 6.30 p.m.
Held at: the James Watt Memorial Institute, Birmingham.
Discussion: the Position of the Cathode Ray Oscillograph in Electrical Engineering.
Opened by: W. Wilson, D.Sc., B.Eng.
(Education Discussion Circle Meeting.)

South Midland Radio Group

Date: April 28. Time: 5,30 p.m.
Held at: the James Watt Memorial Institute, Great Charles Street, Birmingham.
Lecture: Radar Sonde.
By: F. E. Jones, M.B.E., Ph.D., B.Sc.

Southern Centre

Date: April 2. Time: 6.30 p.m.
Held at: the Technical College, Brighton.
Lecture: Inhibited Transformer Oil.
By: W. R. Stoker, B.Sc.(Eng.) and C. N. Thompson, B.Sc.

Lecture: The Stability of Oil in Transformers.
By: P. W. L. Gossling, B.Sc. and L. H. Welch, B.Sc.(Eng.).

Date: April 7. Time: 6.30 p.m.
Held at: the Guildhall, Southampton.
Faraday Lecture: Sound Recording—Home, Professional, Industrial and Scientific Applications.
By: G. F. Dutton, Ph.D., B.Sc.(Eng.).

Date: April 16. Time: 6.30 p.m.
Held at: the Technical College, Weymouth.
Lecture: Computing Machines.
By: J. Bell, M.Sc.

Date: April 30. Time: 7.30 p.m.
Held at: the R.A.E. Technical College, Farnborough, Hants.
Particulars to be announced later.

Western Utilization Group

Date: April 1. Time: 6 p.m.
Held at: the South Wales Institute of Engineers, Park Place, Cardiff.
Conference: Electricity as an Aid to Productivity.

THE INSTITUTION OF ELECTRONICS

Date: April 18. Time: 7 p.m.
Held at: the College of Technology, Manchester.
Lecture: Pumps and Vacuum Technique.
By: D. Latham, B.Sc.

THE INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Date: April 8. Time: 5.30 p.m.
Held at: the I.E.E., Savoy Place, W.C.2.
Lecture: A.C. Signalling—a Review of Current Problems.
By: B. R. Horsfield, A.M.I E.E. and D. C. Smith, B.Sc.(Eng.), A.M.I.E.E.

Informal Meeting

Date: April 23. Time: 5 p.m.
Held at: the Conference Room, 4th Floor, Waterloo Bridge House, London, S.E.1.
Lecture: Explosives for Increased Production.
By: L. W. Barratt, A.M.I.E.E. and S. T. Stevens.

PRESENTATION OF TECHNICAL INFORMATION DISCUSSION GROUP

Date: April 4. Time: 2,30 p.m.-8 p.m.
Held at: University College, Gower Street, London, W.C.1.
Annual Exhibition.

Date: April 22. Time: 6 p.m.
Held at: University College, Gower Street, London, W.C.1.
Lecture: Interpreting Science to the Layman.
By: R. Calder.

THE SOCIETY OF INSTRUMENT TECHNOLOGY

Date: April 29. Time: 7 p.m.
Held at: the Lecture Theatre, the Royal Society of Tropical Medicine and Hygiene, Manson House, Portland Place, W.1.
Lecture: Why the Human Operator ?
By: Dr. W. E. Hick.
(Joint meeting with the Control Section.)

THE SOCIETY OF RELAY ENGINEERS

Date: April 29. Time: 2.30 p.m.
Held at: 21 Bloomsbury Street, London, W.C.1.
Lecture: Cable for Television Relay Systems.
By: H. J. Dixon and Mr. Hinchliffe.

THE TELEVISION SOCIETY

Date: April 2. Time: 6.45 p.m.
Held at: Film House, Wardour Street, London, W.1.
Lecture: A New Television Recording Camera.
By: W. D. Kemp, B.Sc.
(Joint Meeting with the British Kine Society.)

Bristol and South Western Centre

Date: April 1. Time: 7.30 p.m.
Held at: "Carwardines," Baldwin Street, Bristol 1.
Lecture: Back Stage in Television.
By: Peter Bax.

ELECTRONICS IN INDUSTRY

A supplement to Electronic Engineering dealing with recent applications of electronics to control and measurement in manufacturing processes in industry

CONTENTS

THE causes of our post-war economic troubles are so varied, and have been the subject of so much political controversy that it has become very difficult for the layman to understand the reasons for our present predicament. There is no single remedy for our ills, and it is beyond our scope to discuss the thorny problems of industrial relationships, incentives, moral outlook and so on, all of which must be solved before the country regains its economic stability, but whatever the causes, it is quite certain that one of the more important remedies lies in an all round increase in the country's productive effort.

This does not necessarily mean longer hours of work, although this might go some way towards our salvation, but rather that ways and means must be found of achieving the same—or even greater—production for a smaller expenditure of man hours.

This supplement is not intended as a survey of our economic problems as a whole, but it has been designed in a more limited manner to show what has already been done to raise productivity by the intelligent application of the new methods and techniques which electronics can provide for research and manufacturing processes.

In all branches of research, electronics has made outstanding contributions particularly in the field of measurement and today there is scarcely a phenomenon which cannot be investigated electronically; but the adaptation of electronics to industrial uses in manufacturing processes has been considerably slower than expected.

The fundamental principles on which the science of electronics is based are well established, mainly as a result of great development during the war, and in industrial processes there are roughly two sections in which electronics can assist.

The first section is primarily concerned with electronic instrumentation which is finding considerable application in supplementing and replacing existing methods of measurement and control, and the British instrument industry has provided a wide variety of instruments for this purpose ranging from photo-electric counting and control devices to radio active thickness meters and resistance strain gauge analysers.

The other section is that in which electronics is made to take full control of the manufacturing process and it is here where the most promising developments lie, particularly where the process is a continuous one. It is already possible to endow a machine with an electronic "brain" of limited capacity so that the machine will, with variations to suit the particular process, manufacture, count and batch its own product without human intervention, and in such a machine inspection of the product is unnecessary for each stage of the process is electronically controlled. This is by no means as fanciful as it sounds for electronic computors with much greater circuit complexity have been designed and are working twenty-fours daily, with full reliability and accuracy. Components and valves have improved enormously in recent years and an electronic machine can be made to perform just as reliably as a piece of mechanical apparatus. In all sound designs the "failure to safety" principle can be incorporated and in the unlikely event of a failure the electronic machine can always be made to diagnose its own troubles.

In this supplement therefore we have set forth examples of what has already been achieved by both the electronic engineer and the industrial user and since the supplement has been directed towards the industrial user, the circuit diagrams and highly technical descriptions of the internal working of the apparatus have been kept to a minimum. The emphasis has rather been placed on the application side, and it is hoped thereby that industry will be stimulated to review many of its present methods of production.

A second supplement dealing with the same subject is scheduled to appear in the November 1952 issue of ELECTRONIC ENGINEERING.

Industrial Applications of Electronics

By T. E. Goldup,* M.I.E.E.

THE existing and the potential applications of electronics are now so extensive that there is hardly a branch of research, development or production that cannot benefit in some way from this new science. At first sight, therefore, it is rather strange that greater use is not being made of electronics in industry today.

On investigation, however, this situation can be easily appreciated. Electronics is still something of a mystery to many industrial managements, and until more is known by them about this subject, problems which might be solved by electronics will continue to be dealt with by traditional methods. At the same time those who are working in electronics are frequently not aware of the problems of industry and are, therefore, unable to recommend specific applications.

This is one of the major obstacles to the wider adoption of electronics in industry. Neither the electronic engineer nor the industrial engineer can bridge the gap between electronics and industry by himself and any effort which leads to a mutual understanding of common problems should certainly lead to that measure of co-operation without which the full possibilities of electronic applications will never be fully realized.

While the improvement of existing processes accounts for most of the current industrial uses of electronics, it may be in the evolution of entirely new methods that the most important and successful applications will eventually be found. There is, in fact, a great potential field here, much of which is still unexplored. It is, however, a popular misconception that the use of electronics implies the complete replacement of mechanical methods. In actual fact, the bulk of the design and of the equipment in nearly all applications remains mechanical and there is no reason to suppose that future developments will materially alter this balance.

A large number of industrial applications, for example, require the control of some movement, such as the positioning of a component, or the control of a physical property when checking colour, size or shape. The exercise of this control usually involves three stages. The first is in measuring the departure of a particular property from the required standard. The second is in translating the measurement into a form by means of which the control can be applied. And the third is in carrying out the control. It is usually the first of these stages that is purely electronic; the second is usually electro-mechanical, and the third entirely mechanical.

Apart from process control, electronics has created new methods, and modified old methods to such an extent that the modification itself is revolutionary. For example, high frequency heating, which has for over twenty-five years been used in radio valve manufacture, is now successfully applied in the plastics and furniture industries. Ultrasonics, a comparatively recent development, is already finding such widely separated applications as flaw detection and the tinning and soldering of aluminium and other metals producing refractory oxides. Nevertheless, until industry co-operates in practical experimentation, such advances as these cannot be fully exploited.

It is important, of course, to study carefully the economic aspects of these developments. There is clearly no point in employing electronics if it does not lead to a new process or method, or if it does not result in an existing process or method being performed more quickly, more reliably, more accurately or more economically. On the other hand, the correct use of electronics—and collaboration between the industrial engineer and the electronic engineer is the best way of determining this—in almost every case justifies investment in new machinery and equipment. Indeed, with investigation, considerable advantages can be derived even where, on the surface, little improvement over existing methods appears possible.

The development of industrial electronic applications has naturally created many problems, and perhaps the most urgent today is the provision of adequately trained personnel to design, build, install and maintain equipment.

The demands for electronic devices usually emanate from scientists such as the chemist, the physicist or the metallurgist, and they are satisfied in theory by the electronic engineer. But a successful application must depend upon the design and production of these devices by electro-mechanical designers and engineers. The need is for a type of individual virtually new to industry, and the training of such men in increasing numbers is a matter of great moment. This position can only be resolved by starting with young men who have chosen engineering as a career. Technical schools and colleges are becoming more alive to this situation, and one may expect more courses on the principles of electronics and its applications. It will not only be necessary to train men to deal with the many problems arising from electronic applications, but also to give them an outlook which will lead to the discovery of new applications.

In addition to this theoretical training, the required type of individual must also have sound practical training which only industry can provide. In the solution of this problem, therefore, industry's contribution is equally important.

It is understandable that industrial managements should be reluctant to introduce equipment and methods which require special knowledge and skill for their maintenance. But once again, with the assistance of the electronic equipment manufacturer, there is no reason why existing mechanical and electrical engineers should not be given sufficient knowledge and guidance to carry out such work.

To make full use of this new tool, designers and engineers must become accustomed to think in terms of electronics and to give as much consideration to this new technique, when seeking solutions to their problems, as they do to older established methods. This new outlook can only come about by forming the habit of consultation between electronic and industrial engineers. This in turn will lead gradually but surely to collaboration and close mutual understanding in which both sides will have much to give and much to learn, and by which alone electronics can take its proper place in the manufacturing organization of our highly industrialized country.

* *Mullard Ltd.*

Electronics in Automobile Engineering Research . . .

By J. R. Bristow,*
B.Sc., Ph.D., F.Inst.P., A.M.I.Mech.E.

A vehicle being subjected to endurance tests on a section of Belgian pavé surface at the M.I.R.A. Proving Ground.

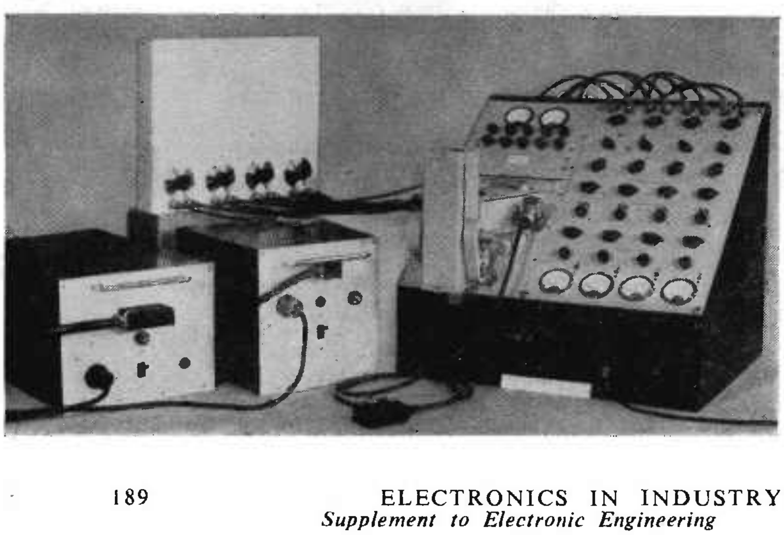
ELECTRICAL methods, mainly electronic, are finding increasing favour in the research and development departments of motor vehicle manufacturers for the measurement of motor vehicle and power unit performance parameters, stress in engine components and body structures, noise, vibration, etc. The Motor Industry Research Association (M.I.R.A.), the co-operative research organization in this country, is playing a leading part in encouraging this trend and in developing suitable test equipment. A description of the work of the Association in this field therefore makes a convenient introduction to electronics in the automobile industry. Although the Association does not seek to enlarge the knowledge, or improve the technique of electronics, but rather to use existing knowledge to provide the tools for mechanical engineering research, it not infrequently happens that the performance demanded of instruments is outside normal practice, and fundamental investigations into electronics have to be undertaken. As a result of this it is often possible to persuade the instrument manufacturers to modify the standard components and equipment they produce. Restricting this article to M.I.R.A.'s activities in the electronic field will necessarily result in some perhaps unexpected omissions, such as, for example, engine indicators, but in any case, it is not intended to mention well-known equipment or to be exhaustive.

Stress in Vehicle Structures

A considerable amount of the Association's work concerns the determination of the stresses in vehicle structures (chassis frame, body members, etc.) and in components under actual working conditions on the road. When, some years ago, the Association first attempted to carry out these measurements, with the aid of wire resistance strain gauges, no suitable equipment was available, the main difficulty being that microphony generated in the valves of the amplifiers, due to road shocks, produced a much greater deflexion on the screen of a normal commercial cathode-ray oscillograph than did the signal from the strain gauge. The only way in which this standard equipment could be used was by mounting it in a very low-frequency suspension system. This seriously restricted its usefulness since it became so bulky that it could not be used in any vehicle smaller than the very largest of private cars. The Association therefore, decided to develop its own equipment for this work and, not only was it necessary that it should be free from microphony without resort to a bulky suspension system, but it should have a true response to steady strains such as those set up when cornering and braking. In addition it should, if possible, be multi-channelled, that is to say, it should be possible to "read" from several strain gauges, on various components, simultaneously. Also it should be no greater in size and weight, with batteries and power supplies, than two passengers and a reasonable amount of luggage, since it is necessary to have a driver and one passenger to operate the equipment. A four-channel dynamic strain recording equipment that was designed and developed to meet these requirements is shown in Fig. 1.

In this equipment the strain gauge bridges are energized at 800c/s, and the strain signals appear as a modulation of this carrier frequency. Freedom from microphony is achieved by using the most non-microphonic valves available and by arranging the amplifiers so that, although they have a high amplification for the wanted signals, they also have a high attenuation for the microphonic frequencies. The pass-band of the amplifiers (produced by stagger-tuned parallel-T feed-back networks) is centred around the carrier frequency (viz. 800c/s) and is 200c/s wide, which is adequate for this type of work, while at the same time providing sufficient attenuation for the microphonic frequencies, which are mostly above 2kc/s with the type of valve used. There is, of course, also a high attenuation below the pass-band and this is very helpful in suppressing the 100c/s and 50c/s "hum," which can be very troublesome on the road where no true earth is available. The strain signals are displayed on four one and a half inch diameter cathode-ray tubes and photographed, together with time-marking signals that are displayed on a fifth

Fig. 1. M.I.R.A. mobile four-channel dynamic strain recording equipment for use with resistance strain gauges in vehicles



* *The Motor Industry Research Association.*

tube, on to thirty-five millimetre film. The records are later examined and measured with the aid of an enlarger and stress from 1ton/sq.in. upwards can be determined with an accuracy of 2 per cent. This degree of accuracy is quite adequate since repeatability on the road is only about 10 per cent.

A considerable number of wire resistance strain gauges are necessary for the thorough investigation of a vehicle structure, a unitary body-chassis ten horsepower car at present being investigated having some five hundred gauges attached to it. Typical records of strain variations taken with this equipment are shown in Fig. 2. In Fig. 2(a) is illustrated the stress vibrations set up in parts of a vehicle, while Figs. 2(b) and (c) show the cyclic variations in stress in a road wheel under working conditions. In order to obtain these latter records, slip-rings are of course necessary to connect the strain gauges on the revolving wheel to the equipment. The variation of resistance at the brush contacts, in the slip-ring arrangement developed for this work, is sufficiently small for the slip-rings to be inserted in the "live" arms of the strain gauge bridges.

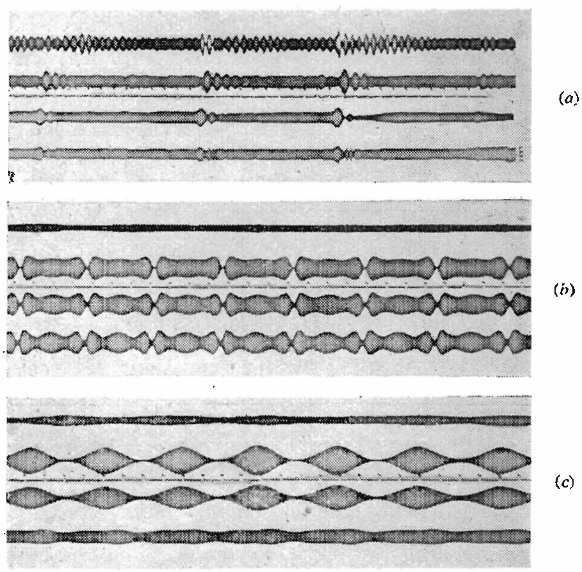


Fig. 2. Strain records recorded as carrier amplitude modulation

(a) From various parts of a vehicle structure on passing over a series of "bumps." Sensitivity 10,000lb/sq.in./mm. (b) and (c) From road wheels showing cyclic variations in strain sensitivity 5,000lb/sq.in/mm. (Timing marks are at 10 per second.)

Torsional Fatigue

Investigation into the strength of, and stresses in, components is well instanced by work on crankshafts. A torsional fatigue testing machine, for testing the strength of crankshafts under fully reversed torsional load is illustrated in Fig. 3. In this machine the torque in the test specimen is maintained constant by electronic means until total failure occurs, when the machine is automatically switched off.

The mechanical part of this equipment is, essentially, a freely suspended system consisting of two large inertia disks connected by extension shafts to either end of a one-throw crankshaft, the crankshaft being the flexible element and at the nodal point of the system when it is in torsional oscillation. The system is maintained in oscillation, in a simple one node "free ended" mode, by means of an electric motor that drives, through a flexible rubber coupling, an out-of-balance mass which is attached to one of the inertia disks. The machine is designed to run near resonance, at an input speed of 3,000 R.P.M., with a dynamic magnifier of about ten over a range of torque of 12,000lb/in. to 35,000lb/in. Running near, but not at, resonance, the torque in the system can be controlled by varying the speed of the driving motor and this is done, by electronic means, in such a way that the torque is maintained constant to within 2 per cent, and is usually constant to better than 1 per cent for most of the test run. It is of interest to note that in order to keep the torque constant to within 1 per cent in this machine the speed must be controlled to better than one part in six thousand.

The torque in the system is measured by means of a capacitor pick-up unit (the change in capacitance of which is proportional to the torque in the shaft) attached to one of the extension shafts. The pick-up controls the frequency of a valve oscillator, the frequency of which will thus be a measure of the torque. The signal from the oscillator is fed through a discriminating circuit to a diode detector stage, the output of which is fed to a D.C. voltmeter and to a peak reading A.C. valve-voltmeter. The D.C. meter indicates static torque and the A.C. meter peak dynamic torque.

The speed of the driving motor is automatically controlled by varying its field current and it was found to be desirable to have this control in two parts. The first, with negligible time lag, corrects for the small but rapid and sporadic fluctuations and the second to correct for greater, but very slow, changes due to the warming-up of the motor, changes of damping capacity of the test specimen, etc.

Complementary to the determination of the fatigue strength of crankshafts is the measurement of the stress to which they are subjected when working in an engine. Since this work is being carried out on a test-bed engine, commercially available cathode-ray oscillograph and recording equipment can be used. The wire resistance strain gauges that are used to make these measurements are attached to the webs of the crankshaft to form a complete bridge and are wired in such a way as to indicate bending but to be insensitive to torsion, and vice-versa. The connexions to the gauges are of course made via slip rings. A record of the cyclic variation of stress in a crankshaft is shown in Fig. 4.

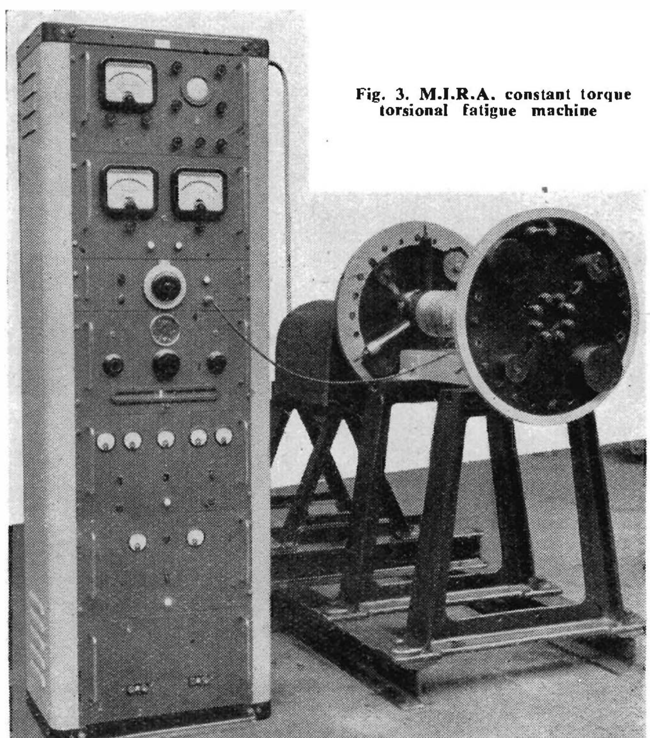


Fig. 3. M.I.R.A. constant torque torsional fatigue machine

Road Performance Parameters

The basic road performance parameters that have to be measured are velocity, acceleration and deceleration (braking).

Electronic timing equipment, that will measure speed with an accuracy of 0·2 per cent, has been installed on one of the roadways at the Association's proving ground. Two projector lamps, spaced fifty feet apart along the track, throw a narrow beam of light across the width of the track on to two photoelectric cells. The passage of a vehicle through the light beams produces a pulse in the relevant photocell unit and these pulses are conducted by overhead cables to a hut in which the measuring equipment is housed. The actual measurement of the time interval, from which the speed of the vehicle over the fifty foot timing length can be calculated, is made by means of trigger circuits and electronic counters in conjunction with a stable oscillator. The pulses generated as a vehicle enters and leaves the timing section actuate a trigger circuit, this in turn switches the output of a 100kc/s oscillator to decade counters, the number of cycles counted thus being an accurate measure of the time interval. The decade counters are of conventional design while the oscillator is crystal controlled and accurately adjusted to 100kc/s $\pm$ 0·5c/s by beating its second harmonic against the B.B.C's 200kc/s transmitter. There are, in fact, two timing lengths, one at either end of the track, so that speeds can be measured in both directions, i.e., up and down wind. The accuracy of this equipment is estimated at better than 0·2 per cent and within this limit of accuracy the section of track used is sufficiently level.

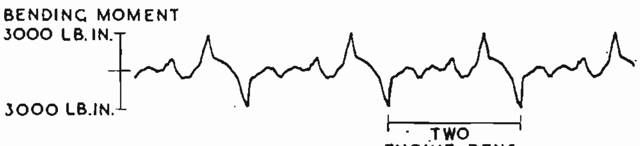


Fig. 4. Cyclic variation of strain in the crankshaft of a test-bed I.C. engine

For measuring the acceleration and deceleration of vehicles the Association has constructed accelerometers of various types. To measure deceleration, during braking, inductance type accelerometers are used in which a damped spring-controlled iron mass, moves between the faces of two iron cored inductance coils. The two coils form the opposite arms of a rectifier Wheatstone bridge the output of which is indicated on a D.C. galvanometer having a scale calibrated directly in percentage *g*. This equipment is used to indicate the mean deceleration during that part of the braking cycle when deceleration is sensibly constant. Brake pedal pressure units, with a pressure cell attached to the brake pedal, have been constructed on the same principle. Equipment employing these two units, in conjunction with a commercial two-channel pen recorder, for recording the whole of the deceleration and pedal pressure cycle is illustrated in Fig. 5(a).

Pedal pressure indicators and accelerometers have also been constructed using wire resistance strain gauges. A pedal pressure unit of this type, in which pressure is applied to the brake pedal through a specially designed stress member to which strain gauges are attached, is illustrated in Fig. 6. The gauges form the four arms of a Wheatstone bridge, the out-of-balance signal being indicated on a galvanometer, the scale of which is calibrated in pounds pressure. Two types of unbonded wire resistance strain gauge accelerometers have been constructed for use with the previously described dynamic strain recording equipment. These have ranges of up to 3*g* and 13*g* with sensitivities of 0·30mV/volt/*g* and 0·81mV/volt/*g* respectively and are used for the study of vehicle motions in connexion with riding qualities, etc.

Resistance strain gauges and inductance gauges are also used for the measurement of steering torque and road wheel torque. In the equipment for the former, the steering wheel shown in Fig. 6 is clamped on to the normal steering wheel of the vehicle, so that the steering torque passes from the added wheel to the normal wheel via a stress member fitted with sets of strain gauges. The torque is indicated on a meter calibrated in pound-feet. In the road wheel torque meter, Fig. 7, eight pairs of inductance gauges, symmetrically spaced around a specially designed wheel, allow measurement of the angular displacement of the rim relative to the hub. The gauges form the arms of an A.C. rectifier type bridge the out-of-balance current of which is sensibly linear with torque up to 1,000 pound-feet. The out-of-balance current is indicated on a D.C. meter calibrated in torque, speed is indicated by a second meter fed from a tachometer generator built into the wheel.

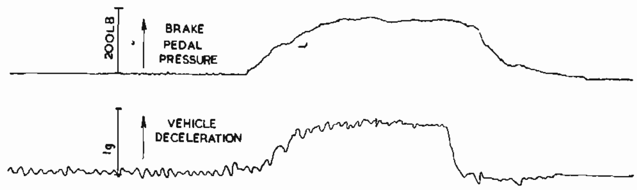


Fig. 5(b). Typical record of brake pedal pressure and vehicle deceleration obtained with equipment shown in Fig. 5(a)

Noise in Vehicles

To conclude this description of some of the Association's activities involving electronic methods of measurement, a brief account of its investigations into noise in vehicles will be given as this is a typical instance where, perhaps unexpectedly in this case, research and normal commercial requirements differ considerably.

The analysis of the noise in a vehicle, when carried out on the road, is very tedious, and it is more convenient to record the noise and subsequently analyse it in the

Fig. 5(a). Brake pedal pressure and vehicle deceleration recording equipment

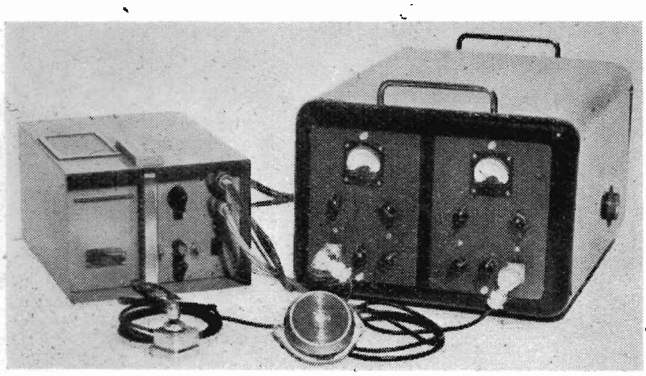
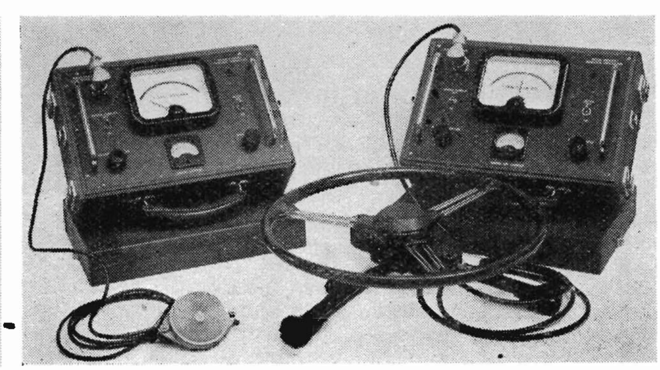


Fig. 6. M.I.R.A. brake pedal pressure and steering torque indicators



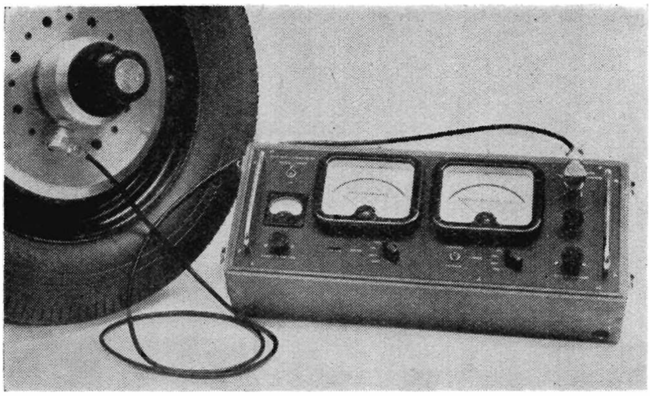


Fig. 7. M.I.R.A. road wheel torquemeter

laboratory. In addition, it is also very useful to be able to play-back the noise for comparison purposes.

It was decided that magnetic tape recording had certain advantages over other media, but this at once produced several problems, the foremost being that, at the time the work was started, tape recorders of a convenient size for operating in a car had a quite inadequate frequency response, while higher grade equipment was far too bulky. With the aid of a commercial tape deck the Association had, therefore, to construct its own instrument and although this is satisfactory for analysing the recorded sound by electrical means it cannot be faithfully reproduced for the following reasons. As can be seen from Fig. 8 the noise in a private car is most intense at low frequencies and this produces two major difficulties. Firstly, the output of normal reproducing systems falls off badly at low frequencies and, although this is not of great importance in the reproduction of speech or music it is serious for car noise. Secondly, the recording and reproduction of intense low frequencies often causes considerable modulation noise although the same recording and reproducing heads and tape are quite satisfactory when used for speech or music. The Association is in close touch with the manufacturers concerning these problems.

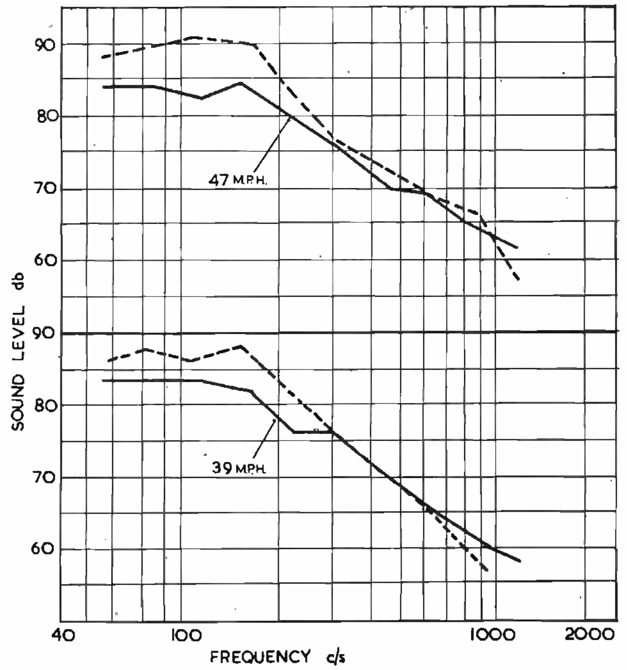


Fig. 8. Typical car noise spectra

The full curves represent measurements taken at the front of the car, while the dotted curves are for the rear.

Conclusion

Although this article is by no means exhaustive it is hoped that the brief description given will indicate the lines along which electronic instruments are being developed and used in research into the problems of design and development of motor vehicles. The physical quantities which it is desired to measure, pressure, torque, power, noise-level, stress, strain, strength, etc., are of course, the same as those in general mechanical engineering, but the problem is obviously more complicated when these measurements have to be taken in a vehicle in motion on the road and, as has been seen, this frequently necessitates the development of specialized test equipment.

Precision Dental Reflectometer

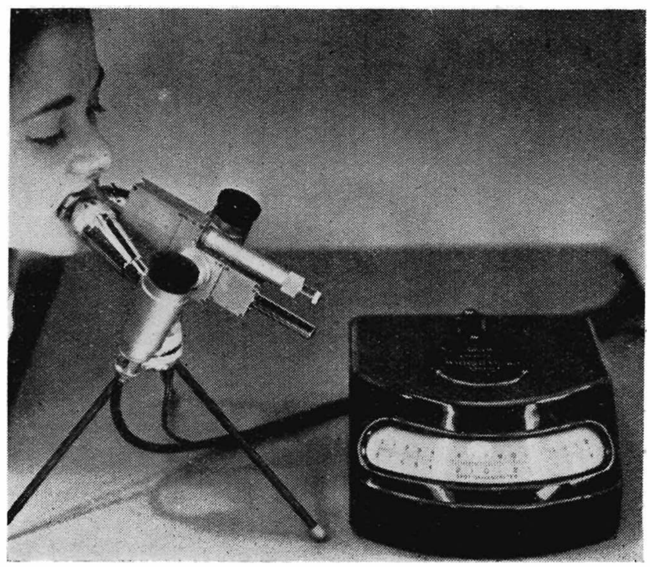
An instrument has recently been designed by Sargrove Electronics Ltd. for the measurement of reflectivity from the surface of a tooth. This instrument, which is illustrated in the adjacent column, requires a separate external plastic jig for each patient under examination. A precision extension piece is fitted into the objective end of the instruments and a small area of the tooth is illuminated at 60° to the normal. The light is broken up into three main components, as follows:

1. The specular reflected component, which is the main component giving the impression of bright teeth (as distinct from whiteness).

2. The diffused reflected component which takes part in the impression of whiteness.

3. The absorbed component which is a loss.

This instrument compares the sum of the reflected components emerging at 60° to the normal with a directly transmitted light through a precision calibrated light slot on the same photocell from the same light projector. The calibration of the light slot has 1,000 divisions and indicates the ratio of the two light values. Due to the use of only one photo-electric cell and one light source, any change in these does not affect the ratio value, and as the instrument has a very rigid precision construction, the repeatable accuracy over long periods (years) is very high.



Automatic Product Handling and Qualitative Control

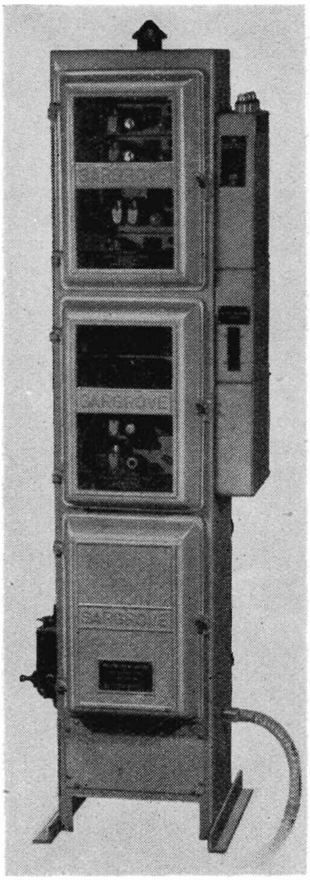
By J. A. Sargrove,* M.I.E.E., M.Brit.I.R.E.

IN many industries such as the plastic, rubber, paper and food production industries, etc., where continuous processes are possible, machinery had reached a stage of semi-automaticity many years before the introduction of electronics. But even so operators were still required to feed material into the production equipment and to do the all-important function of observing the product emerging from the machine and to take action if the quality of the product varied for one reason or another. Finally, operators were still required to carry out several auxiliary operations such as cutting or sealing the semi-finished product, quenching, annealing or transferring the product so produced to further machines for wrapping or packing.

While it had been realized that some of these human functions could be made automatic, it was not clear how all such human activities could be replaced. Thus, in all too many cases the semi-automatic production has been continued year after year without the obvious improvements that could have been adopted. It was argued that as operators would have to be present in any case to perform the handling tasks they could equally well perform the control function at the same time.

This combination of tasks in a smaller number of operators on a production line has not resulted, however, in the hoped for economies, and in many cases has decreased the uniformity in quality and increased scrap, due to the fact that human beings are neither untiring nor infallible; further, the ability to observe small variations in quality decreases as they get more tired.

Clearly a case exists for making a semi-automatic plant wholly automatic but it can only be done by equipping it with automatic inspection means and error-actuated controls. Quite obviously, and this is very important, the product handling must be performed by other than human means. Thus a product becomes more uniform, scrap and waste are reduced, and above all, production costs are less than by the older procedure, even when allowing for depreciation on the new automatic equipment.



The control cubicle containing the electronic control apparatus of the extrusion plant and electronic micrometer.

A good way to achieve the desired results is to combine specially designed electronic inspection and control devices with specially designed machinery that can be electrically operated, though the actual motive power may be derived from pneumatic, hydraulic or mechanical motors in the broadest sense.

* *Sargrove Electronics, Ltd.*

To achieve the desired result the variable factors influencing the quality and quantity of the product must be determined. It must be clear what actions the operator has to perform so that automatic equipment can carry out all these functions just as well as the human operator.

If the equipment is properly designed it will continue to perform these functions to the highest standard, and unlike the human operator it will not tire. Furthermore it can be made to give better results than the average human operator. Obviously the evolved mechanism need only be endowed with sufficient brain capacity for the tasks it has to perform. The sensing means which are to feed the information into the automatic brain need only observe within a limited range the variations of the various factors that affect the product.

Electronic techniques usually provide the best means for evolving many observation organs, for carrying out the thinking functions required to accomplish quality control and the timed stimuli to actuate various special mechanisms. Also they provide the easiest means of making the equipment functionally flexible.

The special mechanisms are usually operated by electrical, pneumatic or hydraulic means but actuated only when the electronic devices command them. A specific example will now be described to illustrate how the above principles are put into effect. Obviously every production task presents its own problems and only those experienced in these techniques can readily visualize the best way of achieving a wholly automatic plant.

Plastic Extrusion of Electrical Cable Sheathing

In the established production methods which have been practised for past decades in this country and abroad a large extrusion machine is used into which the plastic material, mostly in chip form, is poured. The extrusion machine functions on the same principle as the domestic mincing machine except that it is much larger. There is a large diameter horizontal shaft with a screw thread lying in a closely fitting cylindrical barrel, occupying the main body of the machine. This screw shaft is driven by a motor through a gear-box at a few revolutions per minute and has a central hole right along its entire length allowing the unsheathed metal wire to pass through it from a spool at the rear of the machine and to emerge sheathed in plastic material at the nozzle. At the rear of the machine (on the right in the main illustration) there is a hopper-like entry to the grooved screw into which chips of unplasticized raw material are fed. This was usually done by hand with a scoop, or by some semi-automatic device, which required adjusting by an operator.

The raw material moves along the screw and is propelled within the barrel into the head where plasticization of the material takes place under considerable pressure and temperature rise. The plastic material is forced into the nozzle on the head which carries the die through which the material emerges as a soft tube-like sheathing over the metal wire. The soft sheathing has now to be cooled by drawing the wire and its sheathing through cooling water until at least the outer skin is hard enough to be handled without deformation. The towing of the wire is done at a distant point by a variable speed geared capstan, where the sheathing is cool and hard.

Automatic Control of Diameter

Due to the nature of the plastic material the extruded hot soft sheathing expands immediately on emerging from the die. The final external diameter of sheathed electric wire is very important and must be held to close limits, particularly if it is intended to be incorporated in a multicore cable. Therefore, if scrap is to be avoided the rate of expansion of the sheath after leaving the die is of vital importance. On analysing the problem it is found that apart from the elastic coefficient of the particular material, the final diameter is a function of

(1) the speed of the feed screw;
(2) the head of material in the intake hopper;
(3) the temperature of the compression chamber in the head;
(4) the temperature of the die or dies;
(5) the velocity of the towing capstan;
(6) the peripheral speed of the take up spool or drum.

If the speed of the towing capstan is changed while the extrusion rate remains constant the sheath diameter will be correspondingly altered. Usually this can be corrected by manual adjustment of the variable speed gear box driving the towing capstan after the operator has used a " go " and " no go " gauge to test the diameter of the sheathing. Obviously this procedure is not very satisfactory over long periods of production and continuous indication of diameter to a much greater accuracy is required if a constant diameter is to be maintained.

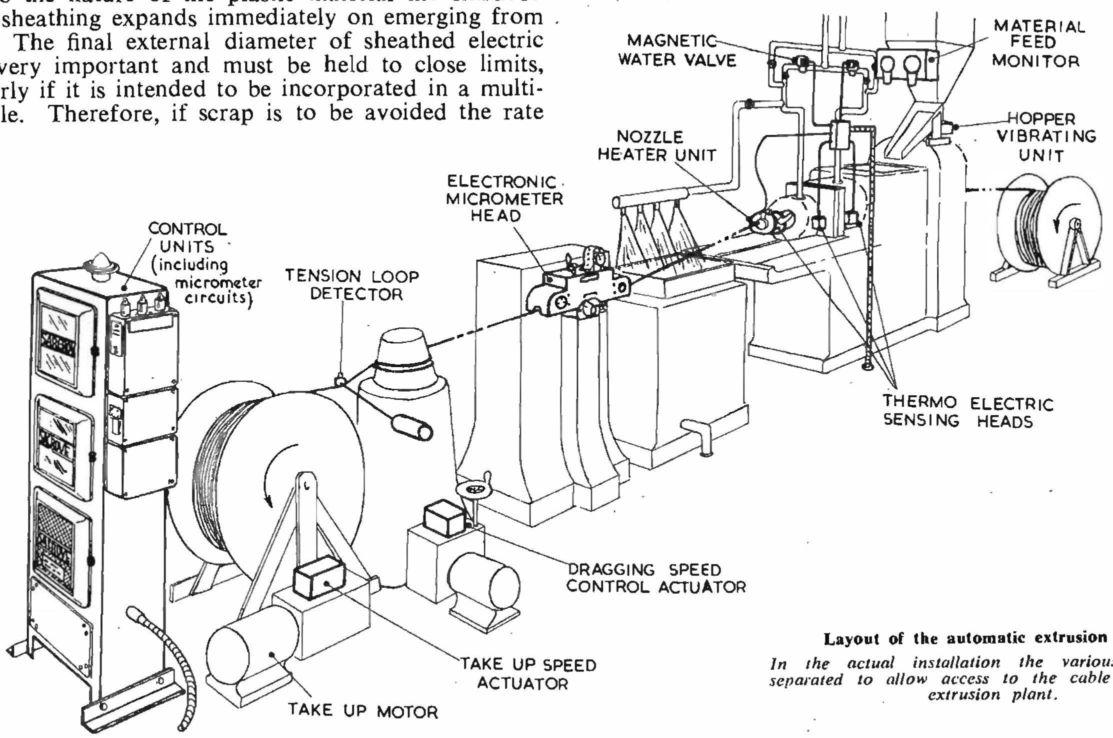
Electronic Micrometer

Clearly a very special instrument will be required for continuously measuring the diameter of a sheathed wire moving at a considerable speed (sometimes as high as 2,000ft per minute) under the usual factory conditions which obtain. Such an instrument must have a detection sensitivity of the order of 0·0001in. and at the same time be capable of withstanding shock and absorbing a very high degree of overload.

It should also be immune to changes of temperature, barometric pressure and to mains supply fluctuations.

An electronic micrometer meeting these requirements is being put into production by the author's firm. This is based on development work carried out by the National Physical Laboratory in conjunction with Messrs. W. T. Henley's Telegraph Works Co., Ltd.

This instrument which is shown in the main illustration, consists of two main elements, namely, the continuous measuring head itself and the electronic control system.



Layout of the automatic extrusion plant

In the actual installation the various units are separated to allow access to the cable drums and extrusion plant.

The head is totally enclosed and will operate continuously without being in any way affected by local conditions of dirt, dust, or splashing from cooling water. Similarly, the control circuit is sealed against dirt, dust and splashing and is mounted in the main cubicle containing all the other electronic control circuits of the extrusion plant.

The measurement takes place in the head between a precision-built anvil roller of 3in. diameter located underneath the cable and a stylus arm balanced on precision bearings, with a probe consisting of a smaller tungsten carbide tipped cylinder which rests lightly on the cable.

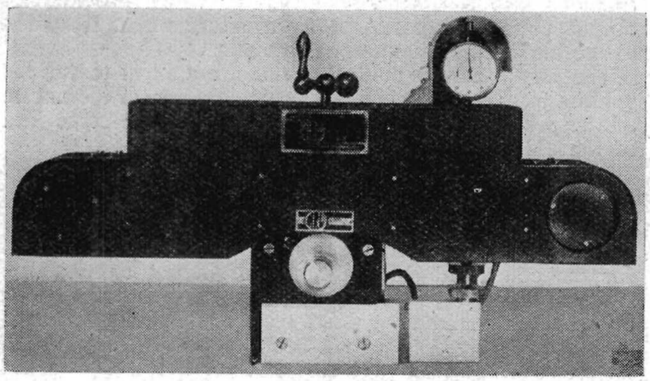
The deviations of diameter from the preset standard are displayed on a large scale instrument having a full scale range of ± 0·001in. and this can be mounted at any distance from the measuring head. Diameter deviations can be corrected by adjustment of the speed of the towing capstan.

Automatic Material Feed and Pressure Control

The screw feed driving motor as well as the towing capstan can be kept at reasonably constant speed irrespective of load by merely making them more powerful than required. This disposes of factors 1 and 5, but hitherto the level of the chip-feed (factor 2) could only be kept reasonably constant by continual attention on the part of the operator.

The same operator was also expected to maintain constant watch on two temperatures (factors 3 and 4). The body temperature was maintained by manually varying the flow of cooling water, the head temperature by varying a mixture of steam and water in the jacket, while the nozzle and die temperatures were held at what was judged to be the right temperature by heating them by a series of small gas jets and periodically checking by touch aided by a pyrometer and by visually observing the consistency and diameter of the emerging sheath. All these factors tended to vary at random and the operator wrestled as well as she could to maintain a good and consistent quality.

All these problems can now be solved by means of electronic control devices.



The electronic micrometer head

The diameter can be set to the required value by adjustment of the hand-wheel and is indicated on the clock gauge.

The raw material feed can be made to govern the flow of a vibratory conveyor from an adjacent large hopper into the small entry hopper. A "photo-electric material feed monitor" was substituted for the operator and consisted of a specially designed optical system looking down into the mouth of the extruder on the feed screw, and a photo-electric cell coupled to a light quantity grading circuit. The photo-electric light grading circuit operates the vibratory conveyor through a short-term timer-circuit so that as soon as the feed screw is even partially uncovered the chips are induced to flow and ceases when the feed screw is completely covered. The circuit is completely stabilized and it gives a much more accurate feed rate in strict obedience to the demand of the extruder.

Accurate Temperature Control

For accurate temperature control something better than conventional thermostats is required. Stabilized electronic amplifiers are used in conjunction with special fast-acting thermo-electric sensing elements built into blocks of heat conducting material and solidly affixed to specially machined faces on the cast iron parts of the extruder. A feature of the fast-acting sensing element is its ability to detect the very small beginnings of a change of temperature. It should not be forgotten that the thermal inertia of the steam jackets is large so that the sensing elements must almost anticipate a change. The thermo-electric elements are able to discern a change in temperature of 0·01°C and in conjunction with the amplifiers and controlled steam and/or water valves maintain constant the temperature to within 0·1°C. There is a particular problem in controlling steam and water jacket temperatures. If, when a rise of temperature is sensed, cooling water were admitted for as long as it takes for the temperature to fall to the required level, then on closing the water valve the temperature of the jacket would continue to cool as the added cold water absorbed some of the latent heat of the steam. Hence a circuit known as an electronic quenching switch is interposed between the temperature sensing circuit and the electromagnetic cooling water valve. This allows water to be admitted to the jacket only in timed spurts and at timed intervals. These times are pre-set to suit a particular machine and the best conditions of the process. The cooling pulses cease when the temperature is just below that required and start again when just above.

The previously mentioned automatic material feed and the precision temperature control of the three regions of the extruding head have enabled the machine to continue working unattended for long periods after the initial starting up period.

Maintaining Constant Tension on the Take-up Drum

Since the towing capstan speed is varied to compensate for the tendencies that affect the sheath diameter it is obvious that the peripheral speed of the take-up drum must be a direct slave of the wire speed which is itself controlled.

There are several ways of ensuring this, but one way that has been found very suitable and reliable is to have a trolley type detector device in contact with the cable loop between the towing capstan and the take-up drum. As more cable is wound on the drum the speed at which the cable is wound on increases unless the rotational speed of the drum is reduced. The trolley detector arm therefore keeps a constant tension in the cable and controls the speed of the take-up drum by feeding information into the appropriate control unit which in turn actuates the variable speed gear box.

Reliability

Fully automatic machines of the type described not only work more consistently than semi-automatic processing equipment tended by human operators, but they will obviously continue their work uninterrupted through lunch time and other breaks. This gives greater productivity without extra effort but in addition also reduces scrap.

No one need fear the installation of such machines on the ground that electronic equipment is perhaps of doubtful reliability. This can only apply to equipment designed without adequate experience.

These automatic machines embody all the most modern electro-mechanical engineering techniques to permit trouble-free long-term operation.

The prototype of an automatic extrusion plant, after its initial teething troubles, had been in use in production for over a year when the sponsoring firm decided to order further machines. The original prototype is still in use now after more than two years.

In another example of a fairly complex electronically controlled printing process about forty valves are used in one equipment. The first such device was supplied two years ago followed by a further six units a year ago. In all nearly 300 valves are used on one factory floor in this works. All that has been required is normal intelligent maintenance and attention, such as any equipment requires, and there has been no trouble due to valve failures or to other causes.

The much abused domestic radio set requires very little attention, yet it is electronic equipment mass produced down to a price, whereas the type of plant described above, which is not mass produced, is primarily designed for stable operation and long term reliability.

Industrial Applications of an Electronic Position Control Servo-Mechanism

By J. L. Gray,* B.Sc.

IN many industrial processes the operator is often required to control the position of some element of that process. He observes the difference between the desired and the actual position of the element at any instant, and this difference which we call the "error" will cause him to send a signal to the muscles of his arm. The signal is in effect amplified in power and translated into movement of the muscle, the movement being controlled in both direction and proportion. The effort so released is directed towards reducing the error to zero. This continuous action therefore provides a guiding action to the process.

Suppose that the edge of a length of material coming off a roll has to be maintained constant with regard to some fixed point, and that the material is wound haphazardly on the roll. As the material is drawn off, its lateral position will vary. This variation may be neutralized by an equal but opposite lateral displacement of the roll. This would be a tedious job for anyone to perform, and the speed with which the operation could be carried out with accuracy would be subject to human limitations. Chief among these is the delay in time between error detection and application of correction, which in the average man is about 0·3 seconds.

Operations such as these are better performed by automatic controls. In the problem first referred to, one way of doing the guiding would be to locate the edge of the material with a lightly pivoted blade pressed against the material, operating contacts and causing an electric motor to rotate in such a direction that correction is applied to the parent reel.

This simple system, too, has several objections, the main ones being:—

(1) There must be a finite distance between blade contacts which will correspond to a zone of no correction.

(2) Errors larger or smaller than this limit will receive the same amount of corrective effort.

(3) Inertia of the motor armature and the load causes correction lags but, worse still, results in over-correction and very often continuous oscillation or "hunting".

Ways and means of overcoming these shortcomings are available. The zone of no correction in (1) can be reduced to a very small amount by using more elaborate error detecting elements and particularly devices which are not "on-off", i.e. those which give an electrical output proportional to the amount of error. This also takes into account the second factor.

The effect of inertia (3) can be neutralized by some form of anticipation and dynamic braking applied before the zero error position is reached.

An effective servo system therefore would comprise the following elements:—

INPUT ELEMENT. A device to detect the error and translate this physical quantity into a proportional electrical potential.

AMPLIFIER. To provide power output proportional to the small electrical input received from the input element in both polarity and amplitude and, in addition, to provide variations in this output power for stable control of motor rotation and precise following of the output position element.

OUTPUT ELEMENT. Consisting of a motor, coupled to the process either directly or more often by a gearbox. Included also is a separate generator which provides an output voltage proportional to armature R.P.M. fed back to the amplifier as a monitoring signal.

The way in which these elements are applied to various guiding problems is bound to vary according to the nature of the problem. A series of examples will give some idea of the ability of the servo.

Textiles

A Cloth Guider

In the textile finishing industry the Pin Stenter is used for the controlled shrinkage and drying of damp cloth. It consists of a pair of parallel rails about 100ft long on which travel moving lines of plates holding series of raked pins. It is desired to transfer the selvedges of the cloth accurately on to these pins. Formerly this operation was done by hand, or relatively crude forms of automatic guiders were used whereby the edge of the cloth was located by a metal blade, which operated contactors starting an electric motor. This motor moved the first pivoting section of the stenter rails laterally to make it meet the cloth selvedge.

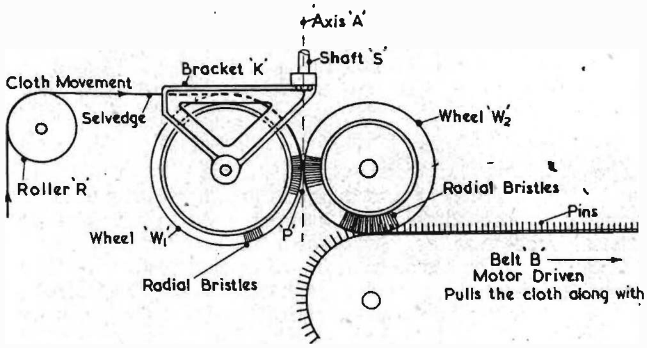


Fig. 1. Cloth guider system

The principle on which the electronic servo functions is illustrated in Fig. 1. A five inch diameter wheel, W_1, is fixed on a bracket (K) and mounted so that it pivots around its own rear edge, the cloth being picked up on its top edge. The servo-mechanism causes the bracket (K) to move in such a way that the top edge of the wheel (W_1) always engages with the selvedge, which is then carried round the wheel to the rear, which being a fixed point in space (P) and being aligned, on installation, with the axis of the pins thus completes the guiding action. Wheel W_2 acts merely as a transfer wheel between W_1 and the pins.

The difficult part of this operation is to steer the bracket and guide wheel in such a manner that the cloth is correctly held by its selvedge. The selvedge is located

* Ferranti, Ltd.

photo-electrically by arranging for it to cut a beam of light passing from a lamp to a barrier-layer type of photo-cell. As the selvedge moves across the photo-cell, so it cuts off more and more light from reaching the cell, thus proportionately altering its electrical output. This small voltage output controls the relatively large power output from the amplifier to which it is fed, this in turn controls the direction and speed of rotation of the servo motor.

The guide wheel bracket is coupled to the motor through reduction gearing, the motor therefore rotates the bracket on which is mounted the photo-cell head and guide wheel until the cloth obscures half the photo-cell, and at the same time lies in its correct position relative to the guide wheel. This process is continuous and a special stabilizing circuit using negative voltage feedback derived from a generator within the motor unit ensures fast following action without "hunting" or over-correction.

Centre Selvedge Slitting

Certain types of fabric are woven "two-in-a-width", that is, two separate lengths are woven simultaneously side-by-side and joined in the middle by weft threads only. It is required at one stage of finishing the fabric to separate it into two distinct pieces.

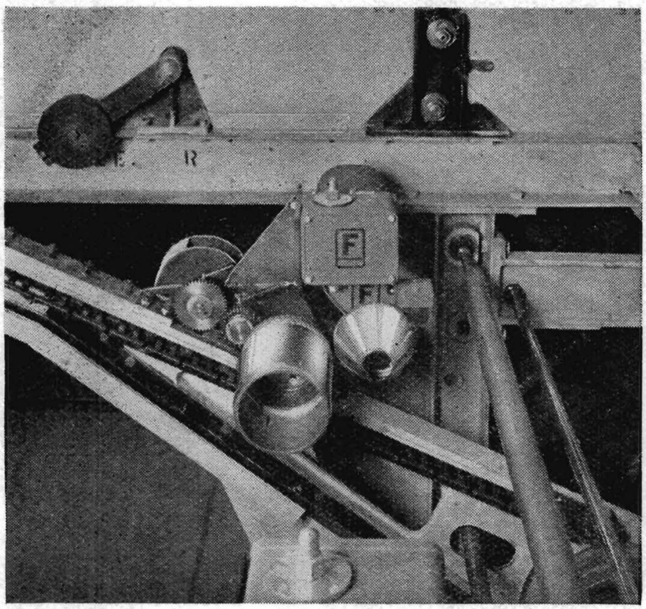


Fig. 2. Guider unit mounted on entry end rail of Double Layer Pin Stenter

This may be done by hand, cutting down the centre with scissors or with a knife, or alternatively by guiding a knife down the centre as the fabric is drawn off some suitable machine such as a stenter. This is a tedious and inefficient method and it is difficult to avoid damaging the fabric as the seam may only be 1/16in. wide. A further method is to pass the lengths either side of a wedge and burst the seam open. This results in a consistently poor finish.

A Line Detector Head, the operation of which depends on an image of the illuminated division being projected by a lens on to two photo-cells, is mounted on a carriage which is laterally positioned by a lead screw driven by the servo-motor in accordance with the output from the head. The motor rotation is such that the head is always positioned centrally over the seam. A rotary knife mounted on the carriage close to the line detector head is driven by a flexible drive from a fixed motor and slits down the centre of the seam. The result is that two processes are combined in one, and apart from this increase in productivity, a much superior finish to the fabric is obtained.

Paper Converting

Web Guiding

Another problem of position control is encountered on machines whose purpose is to slit large rolls of paper into a number of smaller rolls, either with respect to the edge in the case of plain material, or with respect to a line in the case of material which requires to be slit along longitudinal strips of print.

The problem arises due to lateral variations in the position of the paper on the parent roll. It is desired to feed the paper from the roll along a constant path regardless of this variation. Due to the rigidity of the paper it is not possible to deal with it in the manner of cloth.

For edge register the Edge Detector Head is used, while for line register the Line Detector Head is used. These are the types that have already been mentioned in the previous applications. The head in use is a fixture on the frame of the machine and is positioned with its centre at the point

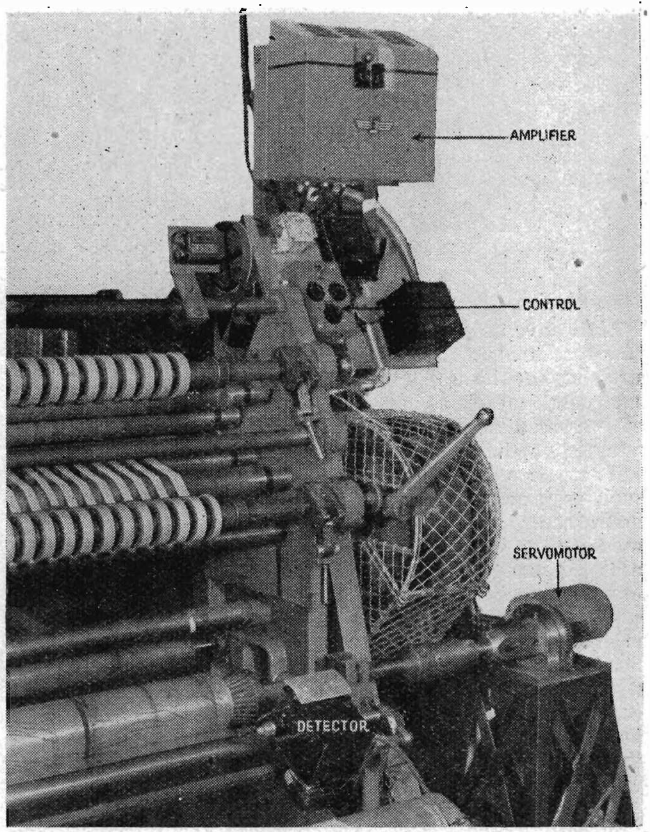


Fig. 3. Servo-pack arranged to provide edge register on clear cellophane

where it is desired to locate the edge or line with reference to the rotary knives.

The output as before is transferred to the amplifier, and the magnified power output causes the motor to rotate. The motor is coupled to the parent roll by a gearbox and a unit that translates the rotary motion into reciprocating motion. A correction is thus applied to the whole parent roll to neutralize the error in the position of the edge of the material coming off it at that moment.

Cardboard Trimming

A guiding application similar to the above has been encountered where it is desired to trim the edge of cardboard packing material.

The board is made up of corrugated cardboard sandwiched between two layers of stiff paper. The edges of the three layers are not necessarily in exact register, but may deviate by some predictable amount. This amount plus a margin for error is required to be trimmed off.

An Edge Detector Head locates the position of the outermost edge and automatically positions an arbor carrying a trimming knife to the correct offset, maintaining the required amount of trimming irrespective of lateral variations in the position of the material as it leaves the machine.

Cable Manufacture

Constant Tension Device

After electric cable has been manufactured it is wound on to a drum of large diameter. If constant tension is not maintained during this process, the transmission characteristics of the cable may be altered. There are several ways of maintaining constant tension, but an inexpensive, simple and effective way is to use the sag in the cable as it is fed to the take-up drum to raise or lower a flag into the Edge Detector Head. This will therefore give an electrical output in accordance with the amount of sag, and therefore the tension, in the cable.

This then controls the speed and direction of rotation of the servomotor. The take-up drum is driven from a constant speed electric motor through a hydraulic variable speed drive. The servomotor by controlling the velocity ratio of this drive will therefore control the tension in the cable at its preset level.

Conclusion

The above are typical examples of the application of a servo-mechanism and it can be seen that its fundamental purpose is to apply suitable corrections to any process or action subect to deviations in order to restore the required set of conditions.

Many different applications are possible because the whole system is built up of standard units, and being electronic it is inherently flexible.

Automatic control can be applied to a very wide field of machinery with considerable improvement in quality and productivity, and reduction in labour cost.

Special Applications to Industry

By J. S. Nisbet,* B.Sc.(Eng.).

THE advantages to be obtained from electronic methods of control in industrial processes have frequently been stressed, but those firms whose manufacturing processes are such that an electronic engineering staff is not required often find difficulty in deciding how these methods can be adopted to their particular requirements.

There is a wide range of electronic control equipment such as process timers which can be supplied as standard instruments, and while the addition of one of these instruments to an existing plant is usually an easy matter this is not necessarily the most satisfactory solution. Where a more extensive redesign of the plant or process seems advisable, the services of one of the firms who specialize in these " one off " applications can be invaluable. These firms have a wide practical experience of the methods by which electronic techniques can be applied reliably and economically to production processes. Even when a firm has its own electronic engineering staff it is often economic to consult these firms with their wider facilities and experience in this field.

When such a redesign is considered it is important for the consultant to have the fullest possible information about the process to be controlled. A discussion between the engineers of both firms is desirable before any decision is made on the type and method of control.

Procedure

The actual development contract can take one of several forms depending on a number of factors. Accurate quotation is usually difficult for this type of work due to the high contingency allowances that must be made. Based on experience with similar projects however, it should be possible to give a reasonably accurate figure. For this reason development contracts of this type are often on a cost-of-work basis. Once some experimental work has been done it is usually much simpler to give an approximate idea of the cost and a common system is to produce a working prototype for a fixed development charge and when this has been completed, make a quotation for the final model. When the work is of a more novel nature a preliminary investigation may be called for to discover the possibilities of the available methods of approach.

Design of Equipment

The development and production of "one-off" equipment differs in many respects from that for a mass-produced article. The process of "Good design by evolution" is absent and other means must be found for producing a reliable, rugged and accurate equipment with as little time and expense as possible.

The wide range of this type of work means that the consulting engineers are called upon to deal with a very wide variety of applications of electronic techniques, but in general the majority of industrial control equipment falls into three sections. The first is the input section which receives the signal which can be in any physical form and converts it into an electrical quantity. This quantity is usually too small for practical purposes and it is then amplified by the second section before being fed to the output section in which it may be counted, measured, or used to operate circuits to restore the input conditions to a standard value. To these three sections may be added a fourth which is the power supply unit. Now, though in any given application one or more of the above units may be of a special nature, it is seldom all are special, and if care is taken to provide the individual units with an adequate reserve a large degree of standardization is possible, with obvious advantages in producing a cheaper and more reliable instrument. These standardized sections can be designed for batch production, using standard layouts and components. The price that must be paid for the versatility of these sections is often increased size, but this, however, is not of major importance in most industrial applications, and any extra cost incurred by using larger and more expensive components than those strictly required is more than offset by the resultant savings.

By this means the elements which have to be designed

* *Formerly of Nash and Thompson, Ltd.*

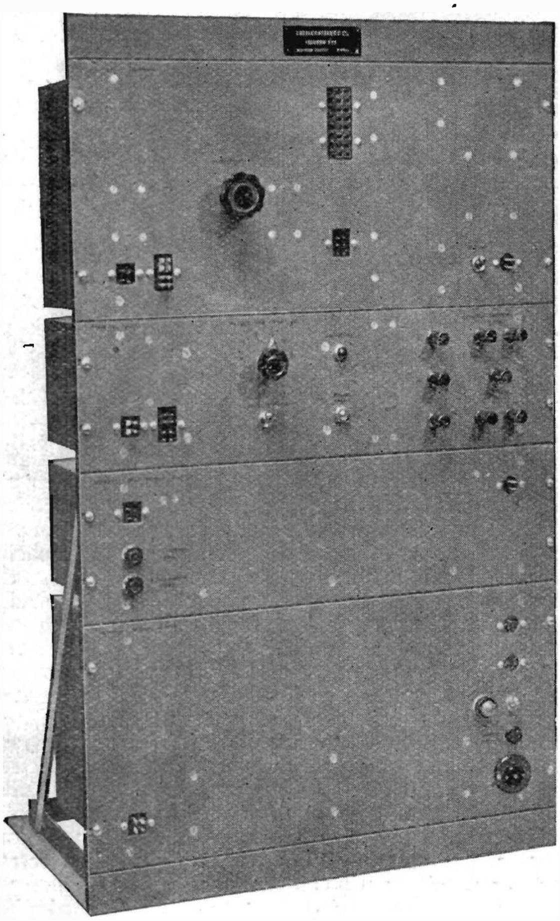
specifically can be kept to a much smaller proportion of the final equipment and correspondingly more time can be spent on their development and testing. This is important as one of the problems in the design of special equipments is to make them rugged and reliable and there is seldom the opportunity for redesign after a comprehensive programme of life testing prototypes. The solution to this problem lies mainly in designing the new sections very conservatively and testing them drastically.

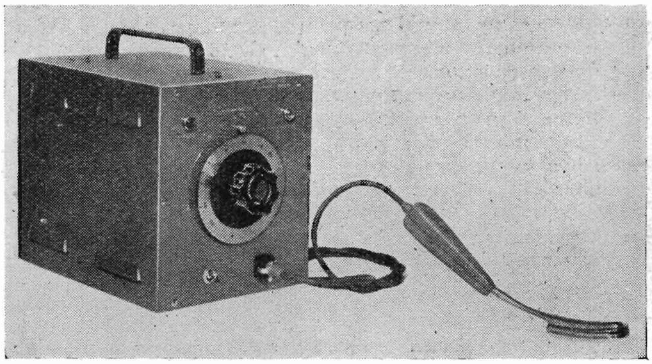
Typical Applications

The activities resulting from these "one off" applications are very extensive and this can best be illustrated by describing a few of the recent projects completed by the firm with which the author was associated. These range from equipment for measuring the torque on dentists' drills under operating conditions to equipment for recording the temperature and humidity every hour inside a packing crate and operating unattended for three months.

An instrument was recently produced for the study of heat exchange problems and investigations on jet engines and is illustrated below. This instrument was installed with only minor modifications on a large ocean going liner to find the actual temperature distribution in the boiler tubes. After installation the ship sailed on its usual run to Australia and by the time Aden was reached a sufficient number of observations had been taken. Film records were then flown back to England and analysed so that all the information was available for remedial action on the boilers by the time the ship returned to its home port.

The instrument designed for heat exchange problems and installed with minor modifications on an ocean going liner.





Heated Spatula and Control Unit.

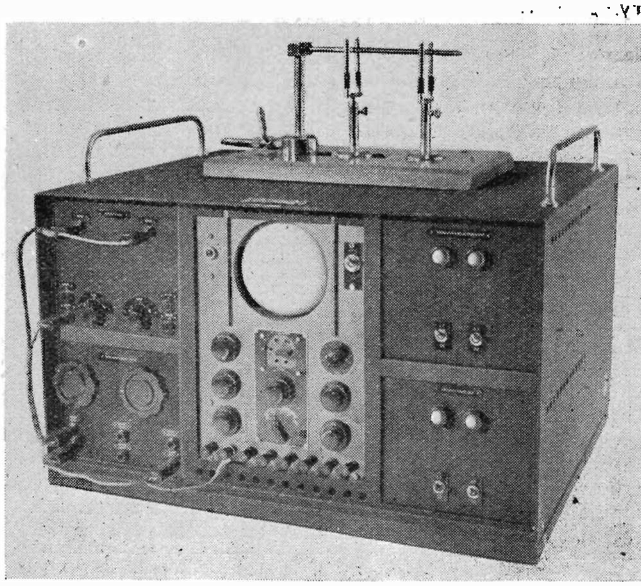
The control unit contains the power supply for the spatulae and the electronic temperature control circuit. Three interchangeable spatulae of different sizes can be used with each unit. A dial setting of temperature is given and a thermal fuse incorporated for additional protection.

A novel application of electronic control of temperature was recently supplied to the National Gallery. In the renovation work carried out at the National Gallery on old and valuable paintings, wax is applied to the canvas with heated spatulae. The temperature at which the wax is applied is very critical and as the spatulae are small, it is difficult to maintain the temperature constant. By electronic control it was found possible to give a dial setting of temperature and to maintain this constant within two degrees centigrade even on the smaller models working on such different bases as copper or canvas.

Another specially designed instrument, known as a Lampadedrometer, was developed for investigation into pin hole gas burners, and was required to measure the time which elapsed between ignition of gas at any two selected burners.

These applications show that it is possible to produce electronic instruments on a "one-off" basis, which are not exorbitantly expensive, and which have a high accuracy with the reliability and ruggedness required for industrial use.

The Lampadedrometer for pin hole gas burner investigation. Over each of the selected orifices is a platinum wire forming one arm of a bridge circuit. When the flame heats the wire the bridge goes out of balance and this is made to energize relays in a clock circuit.



Recent Developments in Dielectric Heating

By V. L. Atkins *

DURING the past few years the heating of non-metallic materials by means of high-frequency currents has been extended to various industries. The principle of heating differs from that of the normal heating processes by convection, conduction and radiation, in that the heat is generated within the mass of material itself, and does not depend on the flow of heat from the outer surfaces. It is the ideal heating process, as the heat energy is generated in the material itself. The rate of heat generated depends upon the voltage and frequency of the electrical energy supplied and on the nature and physical properties of the material itself. Equivalent surface rates of energy transfer 20 to 30 times that obtained by other methods of heating are easily obtained with dielectric heating, with the added advantages of uniform and rapid rate of heating and ease of control over the temperature rise of the material. But this method of heating is expensive, and the cost can make its use uneconomical. However, the preheating of thermosetting plastic compounds, the welding of thermoplastic sheets and the setting of synthetic glues in the wood industry have become firmly established and other applications will no doubt arise as new and improved methods of applying dielectric heating are developed.

The following account gives details of further methods of using dielectric heating and shows how the field of industrial applications is being continuously increased. The article first deals with a particular method of applying dielectric heating to materials which are in "loose" (powder) form, where advantage is taken of the "flowing property" of the material. The second part of the article is concerned with the application of dielectric heating to drying, and describes a method whereby the heating efficiency is improved by utilizing the hot air exhausted from the high frequency generator. Finally, the problem of applying dielectric heating to drying processes is approached with the view of combining it with existing drying plant.

Heating of "loose" materials

A suitable method of applying dielectric heating to materials which are in the form of powders, granules, crystals, etc., is to arrange for the material to pass through vertical electrodes. The method is illustrated in Fig. 1 where the material passes between the two vertical electrode plates. The sides of the chute are constructed of suitable insulating material such as glass or mycalex. The loose material is fed in at the top and taken away from the bottom of the chute by suitable conveyor belts, while the flow of the material is controlled by the speed of conveyors worked in conjunction with the inlet and outlet feed gates. The material is allowed completely to fill the space between the electrodes and as there is no air gap, the maximum voltage gradient can be obtained through the material. This is an important factor, as with the material being in loose form, a higher voltage is required in order that the same rate of heating may be obtained as that when the material is in solid form.

With certain applications it may be necessary to agitate the material as it passes down the chute, to ensure an even flow. This can be carried out by means of a vibrating screen mounted against the earth electrode. The flow can also be assisted if the electrode plates are mounted so that the outlet end is wider than the inlet as shown in Fig. 1. Increasing the distance between the plates at the bottom will reduce the voltage gradient through the material. However, this will not seriously affect the rate of heating, as due to "packing down" of the material, the rate of heating will increase due to the increased density of the material. Furthermore, with certain materials, an increase in temperature results in an increase in the loss factor and therefore, if the voltage gradient is maintained at a constant value, the material will heat up faster as it approaches the outlet end. Thus varying the angle between the two plates can be used to control the characteristic of the heating process. An advantage which this method

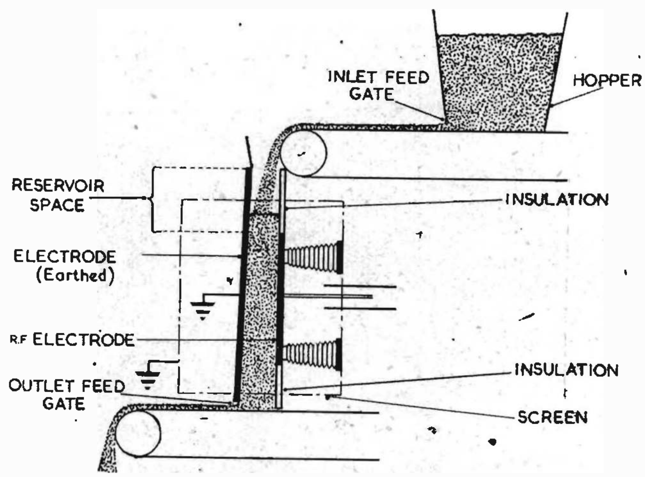


Fig. 1. Diagram to illustrate method used for dielectric heating of "loose" materials

offers is that the material does not control the design of the electrode system as is the case with materials in solid form. Furthermore, if the space between the electrodes is kept completely filled with the material, variation of capacitance will not effect the power factor of the work capacitor. The arrangement thus allows the work to be easily tuned by varying the capacitance of the circuit, with the added advantage that the power factor of the circuit remains substantially constant.

If while the equipment is running, the distance between the plates is altered, the level of the material in the chute will vary unless the flow of the incoming material is correspondingly adjusted. A simpler method is to arrange for a reservoir space to be mounted above the electrode section as shown in Fig. 1. The reservoir section will allow the level of the material in the chute to vary but not to fall below that of the top of the electrode section. Should the level of the material fall below the top of the electrode section, the parallel no-loss capacitance would be increased and the effective power factor of the load reduced. This

* Radio Engineering Department, Metropolitan-Vickers Electrical Co. Ltd.

feature, however, may be used to an advantage when dealing with materials of high loss-factor.

Assuming a constant loading of the generator and a constant flow of material, the temperature rise of the material will remain constant, irrespective of the volume between the plates. This is because the product of the rate of heating and the period of heating for a particular section of the material as it passes down the chute is constant, i.e.,

$$H_1 \times T_1 = H_2 \times T_2$$

where H_1 and H_2 are the rates of heating, T_1 and T_2 are the periods of heating, for the respective distances between the plate of d_1 and d_2.

If the work capacitor is arranged to be the tank capacitor of the oscillator circuit, then in conjunction with a variable anode tap, as illustrated in Fig. 2, an extremely flexible means of adjusting the loading of the oscillator is obtained.

This method of heating loose materials provides a saving in floor space with industrial heating processes where the material can be heated as it passes from one floor level to the floor below and is suitable for such applications where the heating process is one of a series of processes which are carried out on a continuous gravitational system. Examples of materials which can be treated in this manner include cork, starch, flour, chemicals, grain, etc.

Drying

The process of drying by dielectric heating offers some interesting possibilities, the method being more suited to the drying of material in bulk or package form, i.e., bales, rolls, cones, cotton cheeses, wool tops, etc. Most materials when wet have a greater loss factor than when dry, which means that high rates of heating can be easily obtained; examples of such materials include textiles, timber, paper, tobacco, ceramics, etc. Although certain materials have been successfully dried on an experimental basis economic reasons have prevented full-scale production. However, some drying processes require a considerable amount of space and are extremely slow, because of the difficulty in transmitting the latent heat required for evaporation to the centre of the material. Examples of such processes include the drying of cotton cheeses, wool tops, wooden blocks, etc. Through its ability to heat up a material uniformly and rapidly, dielectric heating provides a means of overcoming such difficult drying operations. Although the initial capital and running costs of high frequency equipment are high as compared to steam dryers, the savings in actual drying time, the elimination of auxiliary equipment and the reduced boiler capacity required, may well bring the final operating costs to an economical level. A desirable feature which dielectric heating offers to drying operations is that by controlling the amount of power being delivered by the equipment, the rate of evaporation can be controlled to fine limits and the material dried out to any desired moisture content. This controlling factor of drying is one of the major problems associated with normal conventional drying methods. In many cases where hygroscopic materials are concerned, it is a usual practice to dry the material out beyond the natural regain value in order to ensure that all the material is dried to the same level. This involves considerable waste of both time and heat. Furthermore, the initial moisture content of the material before drying is not the same for each sample of material. This means that the drying operation must be able to deal with the maximum initial moisture content that is likely to occur. In this respect, dielectric heating has the unique advantage that even though different samples contain initially varying amounts of moisture, towards the end of the drying period, the moisture content of all samples will tend to be the same. The reason for this is that the loss factor increases rapidly as the moisture content of the material increases from zero to what is termed the "critical" moisture content point (which for most materials is in the order of 15 per cent to 30 per cent of the dry weight). Thus as drying proceeds for a particular sample that has passed the "critical" moisture content point, the rate of heating will gradually decrease. Therefore the difference of moisture content which may exist between two identical samples at the beginning of the drying period, will be reduced towards the end. Fig. 3 illustrates a typical curve showing variation of power factor against moisture content. Fig. 4 illustrates the "levelling-out" effect obtained when two identical samples of material, one containing 20 per cent more moisture than the other, were dried together in a dielectric heater. The characteristic of the rate of evaporation curve is also governed by the rate of rise in temperature of the material which occurs at the commencement of heating, this being dependent upon the power factor as determined by the initial moisture content. This, as shown in Fig. 4 can also assist towards "levelling-out" any differences in moisture content. For if, due to the lower value in power factor, the sample containing the less amount of moisture, reaches its maximum temperature at a point somewhat later than that of the other sample, then there will be a correspondingly delay in time between the points where the maximum rates of evaporation are reached. This is illustrated in Fig. 4 by the points marked P.

Although dielectric heating does enable a large mass of material to be heated up very rapidly, the maximum rate of evaporation is limited by the rate at which the moisture can diffuse through the material without causing damage. Increasing the rate of heating will increase the internal pressure developed and if this does not allow the drying cycle to be reduced considerably then it is not likely that the use of dielectric heating will be justified.

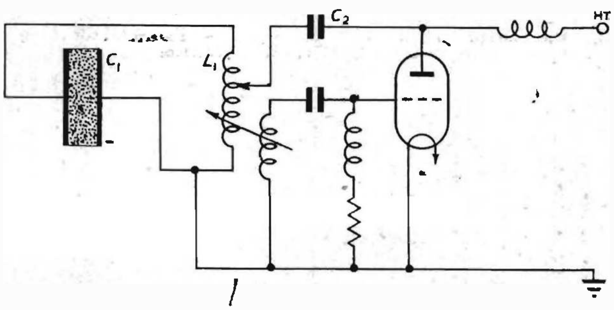


Fig. 2. Circuit showing simple oscillator unit (inductive feed back)

The material to be heated forms the dielectric of the tank capacitor C_1. The capacitor C_2 prevents the H.T. supply feeding through to the tank circuit, and thus allows one plate of the work capacitor to be connected to earth.

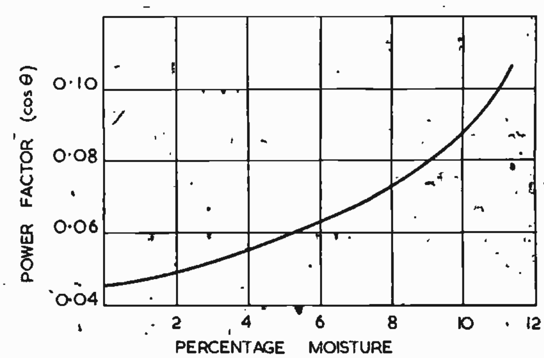


Fig. 3. Variation of power factor with moisture content (Spruce wood at 35Mc/s)

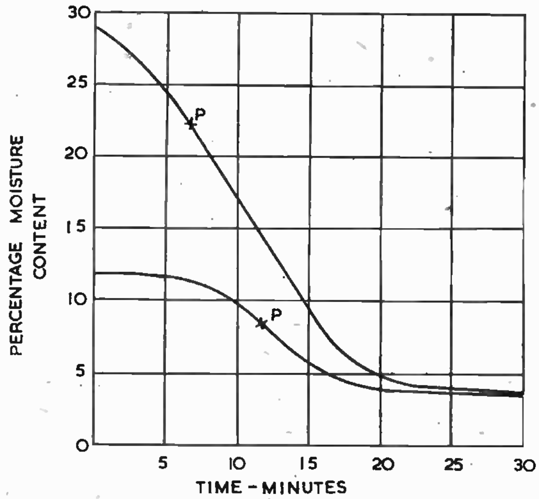


Fig. 4. R.F. drying curves of two samples of material containing different initial moisture content

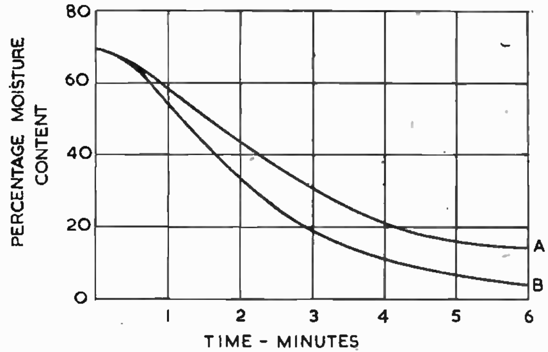
Method of Improving Efficiency

A method whereby the overall thermal efficiency of dielectric heating as applied to drying operations can be increased requires mentioning, as it is primarily the cost that has prevented the method being more widely employed in industry.

The thermal efficiency of a high frequency generator is considerably reduced by the fact that the oscillator valve and associated tank circuit dissipate in the form of heat 30-40 per cent of the total input power. In most types of equipment these components are normally cooled by means of air blast which is usually exhausted direct to the atmosphere. In certain cases this hot air of low relative humidity is blown into the high frequency heating chamber in order to assist in the removing of water vapour released in the drying process. This, however, has the disadvantage that as the temperature of outlet air of the oscillator is usually much less than the temperature to which the material is being raised (100°C for evaporation of moisture at atmospheric pressure), the circulating air will tend to cool the material. Fig. 5 shows drying curves for two sample woollen cheeses, one of which was exposed to the air draught from the oscillator unit, with the result that its rate of drying was reduced as indicated.

Furthermore, in the drying of fibrous materials such as wool or cotton the relative cool air flowing across the surface of the material causes small droplets of moisture to condense on the trailing ends of loose fibres. This is considered to be due to the fact that if the rate at which the water is being evaporated is greater than the amount which the air flowing across the surface can absorb, a

Fig. 5. Curve illustrating the retarding of the rate of evaporation by subjecting the material to the flow of air from the R.F. generator
Sample "A" subjected to air flow from generator.



pocket of saturated water vapour will form around the surface of the material. This, on being cooled by the air stream, will condense on the loose ends of the fibres. Due to the capillary action, the moisture will diffuse back into the material and further energy is required to evaporate it again, its original latent heat having been used to heat the air.

In the particular application described, which is concerned with the drying of wool and cotton packages full advantage is made of the unavoidable waste heat contained in the outlet air of the high frequency generator, to assist in the drying process, thus increasing the overall thermal efficiency.

The drying of the yarn is divided into three distinct stages, for which purpose the equipment is divided into three sections as follows:—

(1) Initial air drying chamber.

(2) R.F. heating chamber.

(3) Final air drying chamber.

The drying is carried out as a continuous process and is illustrated diagrammatically in Fig. 6(a). The packages are placed on a conveyor belt and are fed through each section in turn. The two air drying sections serve as protection

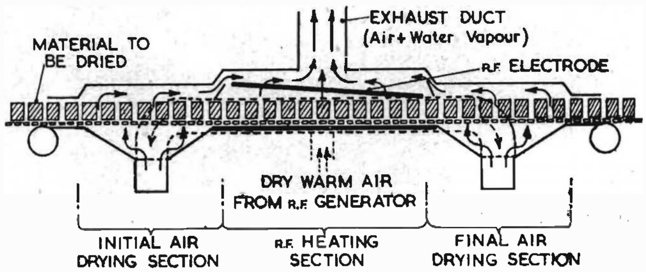


Fig. 6(a). Diagram to illustrate the drying of material assisted by the exhaust air of the R.F. generator

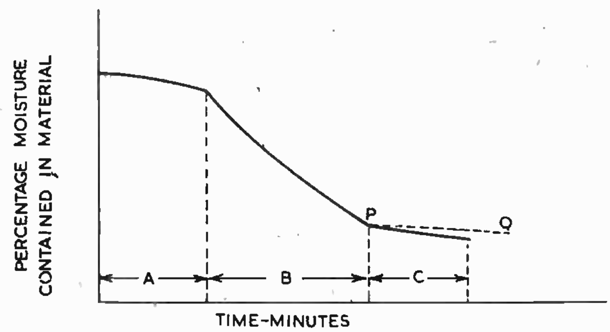


Fig. 6(b). Curve to illustrate the drying of material as it passes through the three sections shown in Fig. 6(a)

A—Initial period to which material is subjected to air flow from generator only. B—Period of R.F. heating only. C—Final drying period where stored internal heat assists the evaporation of moisture into the air stream. (The dotted lines PQ illustrates drying rate when material is allowed to "Cool off" in normal atmosphere.)

tunnels for the live electrodes. The period to which the material is subjected to air circulation in the air drying sections, is based upon obtaining the most suitable conditions of air flow to remove the maximum amount of moisture in a minimum of space.

Initial Air Drying Section

In this section a proportion of the total air flow from the generator is arranged to circulate across the material before it reaches the high frequency heating chamber. During the period that the yarn is passing through this section, a certain amount of moisture will be evaporated by the circulating air, the rate of evaporation being controlled by the wet and dry bulb temperatures and flow conditions of the air. The latent heat of evaporation is supplied from the total heat contained in the air which cools during the process. The drying operation of this section is similar to that of a normal air dryer, except that a high degree of saturation of outlet air is not required, the outlet air in this case being required to assist in the removing of the water vapour produced in the next section.

R.F. Heating Section

Drying in this section depends entirely on the heat being supplied by high-frequency energy. The electrode arrangement consists of an adjustable top plate and an earthed plate over which the conveyor belt slides. It is obvious for this application that an air gap must exist between the top plate and the material. This air gap can be used to provide a certain control over the loading of the generator. By mounting the top electrode at an angle to the horizontal, so as to reduce the air gap towards the dry end of the dryer, the voltage gradient can be increased as the material passes through. This is necessary in order to compensate for the reduction of the loss factor of the material as the moisture content is reduced which results in the rate of heating becoming progressively less as the drying proceeds. Extraction of the bulk of the water vapour generated in this section depends on natural convection currents assisted by the main air flow, which after having passed through the air drying sections, is directed to flow across the top of the high frequency heating chamber. This flow of air is arranged so that it does not come in contact with the material, otherwise as previously explained, condensation will occur on the surface of the material. Due to the inside of the dryer being slightly above atmospheric pressure, the air and water vapour are forced out through an exhaust duct which is mounted above the heating chamber. The amount of air and water vapour which is exhausted through the inlet and outlet openings of the dryer, is kept to a minimum value by the use of special "flap plates."

A further feature incorporated in the dryer is that the main air duct carrying the flow of air from the generator is built into the sides of the high frequency section. This allows some heat exchange to take place between the hot water vapour produced inside the oven and the air flowing along the duct. This heat exchange is increased by the fitting of conducting fins in the air duct. The condensate collecting on the sides of the oven through the heat transfer action is collected and run off along suitable channels. This means that less water vapour is required to be removed by the air through the exhaust duct.

A small quantity of the dry air is directed across the top electrode in order to prevent moisture collecting and dripping down on to the material.

Final Air Drying Section

In the final section of the dryer, the flow of the hot air is directed over the material immediately it leaves the high frequency heating section. Provided the material is not completely dry, moisture will be evaporated by the assisted drying action of the air at a much greater rate than if the material is allowed to cool under normal conditions. If there is no air flow across the material, a stagnant film of saturated air will form around the surface of the material which will retard the rate of evaporation, and a certain amount of the stored heat will be lost through conduction and convection. The principle on which this final drying process depends, is to cool the surface of the material as quickly as possible so that the amount of heat lost through conduction and convection is kept to a minimum. By this means the maximum amount of heat, which is stored in the material and the contained moisture, is utilized to provide the latent heat to assist in further evaporation. As the moisture is evaporated into the air stream, the outside surface of the material will cool rapidly towards the wet bulb temperature of the air. Owing to the low thermal conductivity of the material, the temperature of the centre will not reduce at the same rate. As evaporation proceeds a temperature gradient will therefore exist and heat will flow to the surface where it will be given up as latent heat. Furthermore, owing to the higher internal temperature, there will be a vapour pressure gradient, which will assist the flow of moisture to the outer surfaces. Eventually, the normal evaporating process as based on fundamental psychrometric principles will be reached, when the internal temperature of the material becomes equal to that of the evaporating surface. At this stage, the air must supply the latent heat for further evaporation to take place. Evaporation will cease when the air vapour pressure and the internal vapour pressure of the material are equal. The completion of drying the material in this final section depends upon arranging for the material at the end of the high frequency heating period, to contain the correct amount of moisture. When this has been reduced by the amount evaporated in the final section, it leaves the desired amount required in the finished dried material.

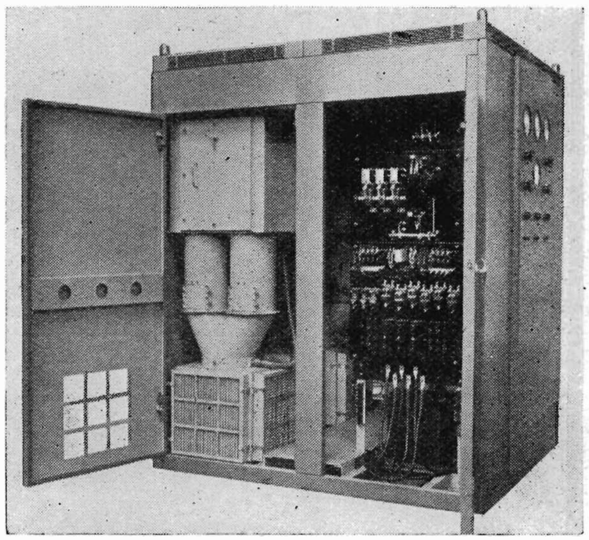


Fig. 7. Typical 30kW generator

The air filter and ducts required for cooling oscillator valves are seen in the left of the cabinet. The hot air when exhausted can be used to assist in the drying process.

A further advantage gained by this final drying off process is that the material can be handled in a very short time after leaving the high frequency heating section.

Apart from the increase in the thermal efficiency obtained by this system, the capacitance of the electrode system can be less than that required when the complete drying process is carried out by dielectric heating. Thus a higher frequency of operation can be used.

The Combination of Dielectric Heating with existing methods of Drying

As previously mentioned, the chief disadvantage of applying dielectric heating to drying processes is the cost. The trend of the future development in this sphere rests upon methods being found whereby dielectric heating can be used to assist rather than replace other drying methods. Dielectric heating is rapid but is expensive, whereas methods which are slow in drying are less expensive. Therefore it is logical to assume that by combining the two heating techniques together, methods of drying should be evolved which should prove to be a means of lowering costs and increasing production. The advantage of such a scheme is that it allows the output of existing plant to be increased without incurring large capital outlay.

The drying curves for most materials follow a similar pattern, although the characteristics of the curve will vary for different materials. Figs. 8(a) and (b) show typical drying and temperature curves for solid material using hot air circulation.

The first stage (A-B) is concerned with raising the temperature of the material to the temperature at which maximum evaporation will take place, which in the case of drying by hot air, is equal to the wet bulb temperature of the air. During this period the rate of evaporation increases until a state of heat transfer equilibrium is reached, where all the heat transferred to the material provides the latent heat of evaporation. The process now enters the second stage of drying (B-C) where the rate of evaporation is constant. During this constant rate period, the rate of evaporation is controlled by the flow conditions and the wet and dry bulb temperatures of the air. The third and final stage (C-D) is reached when the rate of evaporation begins to fall off and the temperature of the material rises to the oven temperature, which in the case of air drying is the dry bulb temperature of the air. The moisture content corresponding to point C is termed the critical moisture content point of the material. The rate of evaporation during the falling-off period is governed by a number of factors involving capillary action, shrinkage, temperature, and diffusion of moisture through the structure of the material. In most drying operations it is the final drying period where the rate of evaporation decreases considerably which presents the greatest difficulty of the drying process. With certain materials the initial warming-up period has to be deliberately retarded in order to prevent excessive surface evaporation taking place, otherwise the surface is liable to become cracked and fractured due to uneven shrinking. It is obvious that it is either in the initial warming-up or falling-off periods that maximum advantage is likely to be gained by the use of dielectric heating.

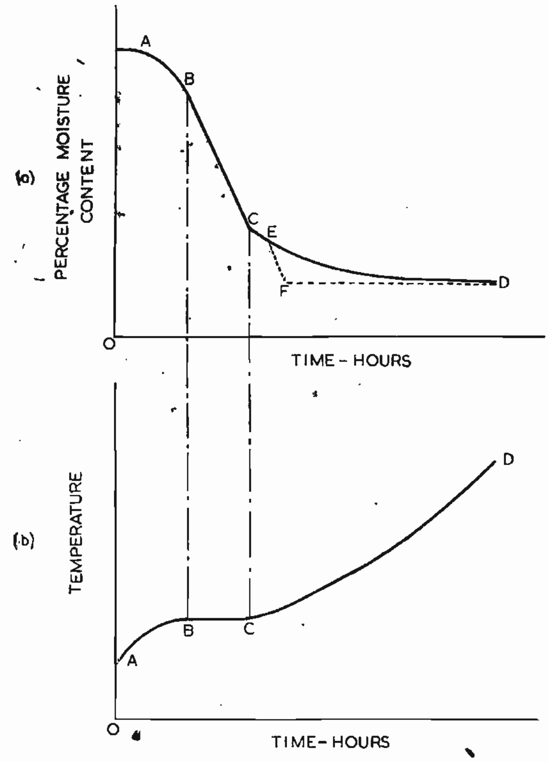


Fig. 8. Typical drying and heating time curves of solid material obtained with normal convection dryers

The dotted line E-F shown in Fig. 8(a) illustrates how the total drying time can be reduced by arranging to change over to dielectric heating during the falling-off period of the evaporation curve. The rate of evaporation obtained by the use of dielectric heating will then depend upon the power of the equipment used.

Cost Studies

In order that dielectric heating as a means of improving an existing drying method may be investigated, it is essential that a detailed cost study of the complete drying process be prepared. This requires the analysis of the various operating costs so that in conjunction with the rate of evaporation curve of the particular material being dried, the cost of drying for different times during the drying cycle can be established. In general the running costs of a drying machine can be divided into two distinct groups. Firstly, there is the cost of providing the essential heat requirements, which is the total amount of heat required to provide the latent heat of evaporation and to raise the temperature of the material and its moisture content to the desired evaporating temperatures. Secondly, there are the fixed running costs of the drying equipment, which includes heat losses, depreciation, electricity to drive fans, etc., handling charges, and various indirect overheads. In applying these costs to the rate of evaporation curve it can be seen that the cost of evaporating moisture at a particular instant of the drying cycle depends upon a fixed constant, which is derived from the essential heat requirements, and a variable factor. The latter is derived from

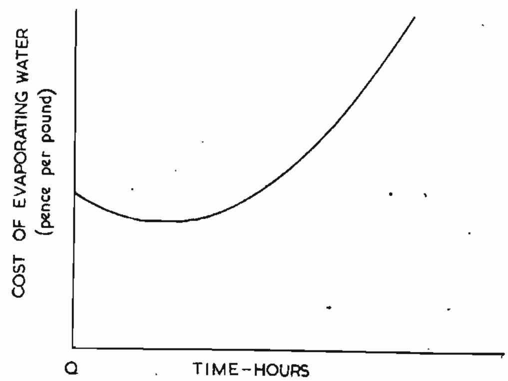


Fig. 9. Curve showing how cost of evaporating water from solid material by a convection dryer varies when based on the rate of evaporation curve

the fixed running costs of the equipment and is dependent upon the rate of evaporation that is occurring at that particular instant. Fig. 9 illustrates an example of a curve showing the cost of evaporating moisture as against time based on the evaporation curve of Fig. 8(a). It is obvious that the maximum operating efficiency of drying occurs during the period of the constant rate of evaporation. After the critical moisture content point has been passed the efficiency is reduced as the rate of evaporation falls off, and towards the end of the drying period, where the rate of evaporation is extremely slow, the cost of drying becomes considerably higher.

If the curve of evaporation cost for any instant of time shows that the cost of evaporating moisture, at a particular time of the drying period, rises above the cost of drying using dielectric heating, then by completing the drying operation with dielectric heating the total drying time and average cost can be reduced.

The time at which change over to dielectric heating produces maximum benefit depends to a large extent on the amount of time that can be saved for the complete drying operation.

In certain drying applications, where the bulk of the moisture is evaporated by means of controlled air circulation, the final cost of drying can be further reduced by arranging for the hot air supplied from the high-frequency generators to supplement the inlet air of the dryer. This reduces the cost of supplying the essential heat requirements of the dryer. In certain cases the power required for the motors to drive the fans of the dryer can also be reduced.

Future progress in the direction of applying dielectric heating as an aid to existing drying operations requires a considerable amount of investigation to be carried out. It is necessary that complete cost analyses, based on the rate of evaporation curves, be obtained for the various drying systems used. Closed co-operation must be established between the high frequency engineer and the industrial heating engineer, both being required to be conversant with the principles and problems associated with the heating technique involved.

Miscellaneous Applications

The number of other industrial heating processes to which dielectric heating has been applied is considerable. Of those which are being put to practical use, although at present only on a limited scale, include: the curing and drying of fibre boards and sand cores, the setting of twist in rayon, the dehydration and sterilization of foodstuffs, and the pre-heating of rubber for moulding.

Further applications will no doubt arise, as the potentialities of this relative new technique of heating are realized in other industries.

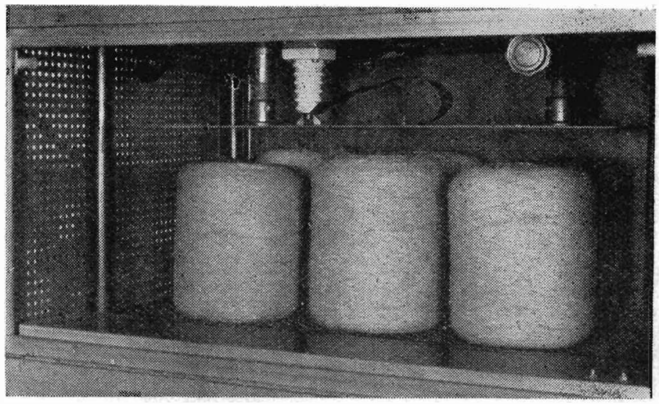


Fig. 10. Wool cheeses being dried by R.F. heating

Acknowledgments

The author wishes to express his thanks to the Directors of Messrs. Metropolitan-Vickers Electrical Co., Ltd., for permission to publish certain details of work carried out in the firm's laboratories.

Batching, Counting and Sorting

By G. C. Shore *

Batching

An example of how electronics can accurately control a mechanical batching device is found in an installation of equipment recently supplied to the Argentine for the rapid and accurate binning of tennis shoe lasts in their correct sizes ready for immediate re-issue to the shoe assembly lines.

Briefly, the operation involves the conveying of lasts in pairs to any one of thirty different storage bins.

The daily output from the factory of tennis shoes is 50,000 pairs per 14-hour working day and the sorting of lasts for this quantity is under the control of three separate operators.

The shoes are cured in pairs while fitted to an aluminium last and after curing and cooling, they are delivered to an automatic stripping machine which deposits the lasts into a hopper and places the shoes on a conveyor for transportation to the next destination.

There is a battery of six stripping machines installed in pairs, each pair controlled by a separate operator who is provided with an electronic console, shown in Fig. 1, by the operation of which he can dispose of the contents of the stripper hoppers.

As the shoes are stripped, the lasts are allowed to accumulate in the hopper until either it is full or the shoe size changes. When either of these conditions occur, it is necessary to despatch the accumulated lasts to their correct bin.

Below the hopper is a conveyor which carries the lasts to a total of thirty different sized bins, the furthest of which is 165ft away and the nearest of which is 57ft away.

Although the conveyor travels at 250ft per minute, the maximum daily production could not be maintained if the same amount of time was allowed for the lasts being dispatched to bin No. 1 as would be, for instance, to bin No. 30. Also, once the first operator has dispatched a batch of lasts to their destination, the operation he has commenced must not be interfered with by either operators 2 or 3, until it has been completed.

The three electronic control consoles, each under the control of one operator, are placed one between each pair of strippers and hoppers.

Each console has a sloping control desk on which are mounted:

- 30 push buttons to control the destination of each battery of lasts.
- 2 push buttons to control the release from the operators' own pair of hoppers.
- 2 indicator lamps (1 red and 1 green).

The function of each button is engraved on the control panel and although the control panels are remotely situated from each other, each is linked with the other two and electronically timed so that once an operation has been started, the other two operators cannot start to discharge and dispose of their lasts until the first operation has been completed.

The conveyor belt travels a total distance of 165ft and the thirty bins are spaced over a total distance of 108ft, allowing the remaining distance to be taken up by the approach to the bins. The belt wall in front of each bin has a hinged section which when placed across the approaching lasts, in the form of a plough, scoops them all into a bin at the pre-determined point.

This plough is operated by double-acting air cylinders which are in turn controlled by a solenoid operated air valve (see Fig. 2).

When the operator selects a push button on the control panel to dispatch the size of last he is then handling, the appropriate solenoid is actuated, operating the cylinder and placing the plough into position.

As previously stated, the consoles are provided with indicator lamps, one red and one green; when no lasts are being dispatched, all signal lamps rest at green, but immediately an operator decides to dispatch a batch of

* *Teledictor, Ltd.*

lasts to a bin, the green lamps are extinguished and replaced by red lamps which remain alight until the operation has been completed when they return to green.

At the same time, a push button has to be operated to enable the operator to obtain release of the lasts from either one or the other of his appropriate hoppers. He therefore selects two buttons, one for the hopper and one for the appropriate bin. This operation immediately neutralizes the remaining four hoppers in the hands of the other operators, none of which will function again until the operation has been completed.

The operator cannot, of course, see the destination to which he has sent a batch of lasts and therefore the console control units are timed to operate only for a sufficient time-interval to enable the cargo to get to its destination, after which interval the timers are released.

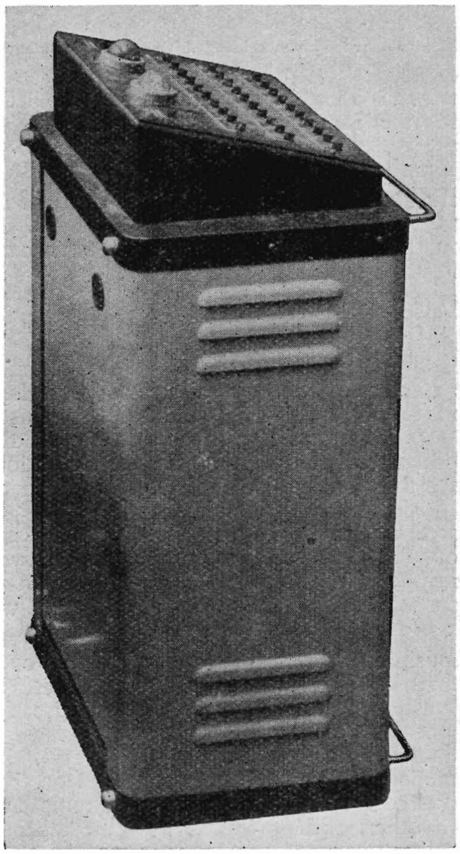


Fig. 1. The electronic control consol with its press-buttons and indicator lamps

In this way a considerable saving of time is effected in making the equipment ready for the next operation and the equipment will handle about 3,600 pairs of lasts per hour. Once the sequence of operations have been started by the operator of any one console, the electronic machines take complete control and until the operations have been completed no other operator can actuate the mechanism. Thus one batch of lasts cannot become mixed with another, and there is no chance of error due to the human element.

The conveyors and associated mechanization were all produced by G. W. King, Ltd., of Hitchin, and the pneumatic equipment, including air valves and cylinders by Lang Pneumatic Ltd., of Wolverhampton.

Counting

A problem was recently encountered by Messrs. Taylor and Challen, Ltd., who were manufacturing a range of coining presses for a foreign power.

It was required that after the coin blanks had been fed to the minting presses, they should no longer be accessible to the operator and that the counter recording the number of coins minted should operate only when a coin had actually passed through the tools and not by the mechanical movement of the press.

The exit of the minted coin is through a completely enclosed hopper chute into a sealed container. A sensing head is built into the hopper chute and as the coin falls after minting it is guided through this head, and by an electronic method actuates an electro-magnetic counter only when completely minted coins pass through. The sensing head is coupled with an electronic unit which in turn passes an energizing impulse to a locked electro-magnetic counter which records numerically the actual coins deposited in the sealed container.

The light beam and photo-electric cell method for counting was ruled out for this particular problem because of the considerable mechanical shock to which presses of this type are subject and which it was considered would render incandescent lamps unreliable.

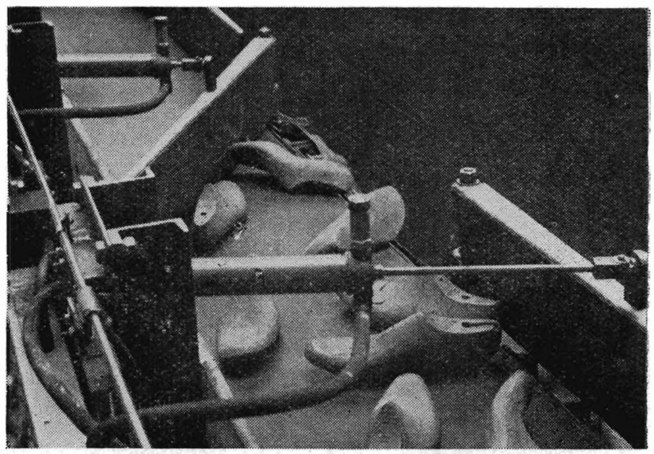


Fig. 2. Shoe lasts being deflected by ploughs into the appropriate bins

As this type of sensing head is in itself essentially a metal detector, it can be used, when assembled in a different form, for the counting of any metal component that may be travelling along a conveyor belt.

Sorting

An example of how an electronic device can be used for the sorting of materials is found in a number of machines which have recently been supplied to the Royal Mint for the sorting of the silver coinage of the Realm.

The machine was required to differentiate between those coins minted from alloys containing silver and those made from cupro-nickel and to have a range of four denominations of currency.

A rotary hopper containing a large quantity of coins feeds these coins at close intervals to a chute where they fall vertically through the sensing head which decides electronically their composition and allows coins containing cupro-nickel to fall straight through to a container and silver coins to be ejected into a separate container.

The electronic unit is so designed that in case of circuit or valve failure, the machine operator is instantly notified and until the machine is mechanically stopped all coins pass automatically to the cupro-nickel container, the silver already sorted thus remaining uncontaminated.

The speed at which this machine is able to operate is partly controlled by the speed at which the mechanical hopper is able to deliver coins to the sensing chute, but the machine is capable of handling eight coins per second or over 150,000 coins per day.

This machine was described in greater detail on page 22 of ELECTRONIC ENGINEERING, January 1952.

Recent Developments in Electronic Engine Indicators

By S. Hill,* M.Sc.

MODERN research and development on fuels and engines depend to an increasing extent on complete and accurate performance data. In addition to actual combustion phenomena within the cylinder, the designer has today to study the movement of valves, the vibration of the frame, the torsional oscillations of the shaft, wave propagation in the exhaust system and many other phenomena.

For this work, particularly with modern high-speed engines, the well-known drum-and-pencil indicator is no longer adequate, chiefly because of the inertia of its moving parts, and an instrument of wider scope is required for serious engine study. The electronic engine indicator with cathode-ray display tube is ideal for this purpose because it is almost entirely free from inertia distortion and because it is readily adaptable to a wide variety of uses. No single unit can, of course, provide all the information required, but the amplifying and cathode-ray tube elements of an electronic system represent an almost ideal nucleus for organising and displaying the information brought to it by various electrical pick-ups fitted to different parts of the engine.

The Standard-Sunbury engine indicator is one such device which is well adapted to the qualitative and quantitative study of a wide variety of performance phenomena in all types of internal combustion engine.

Description of Instrument

The Standard-Sunbury indicator with its associated pick-up units operates on an electro-magnetic principle which is so well known as to need no detailed description. It will suffice, therefore, to outline the main features and some of the applications of the latest, Type F, model.

The improved pick-up units are of two general types, those intended for measuring pressure changes and those designed to indicate mechanical movement. The basic principle of both types is the same, being an electro-magnetic device in which an air gap is varied to produce a proportional E.M.F. The cylinder pressure pick-up units are shown in Fig. 1. In the indicator this E.M.F. is amplified and then serves to control the vertical deflexion of a cathode-ray beam, a horizontal sweep or time base being provided by another device comprising a contact-breaker or alternatively an electro-magnetic trigger connected to the engine shaft. The time base may be calibrated in degrees of crank angle by the same "Sweep Unit." This is done by means of a toothed wheel and an electro-magnetic pick-up for indicating on the screen the passing of the teeth.

Diagrams obtained on the cathode-ray tube are *velocity* or *rate-of-change* diagrams because electro-magnetic pick-ups are essentially differentiating devices. If, for example, a cylinder pressure diagram is displayed, its ordinate will represent the rate of growth or decay of the pressure and its abscissa the angular position of the crank or flywheel.

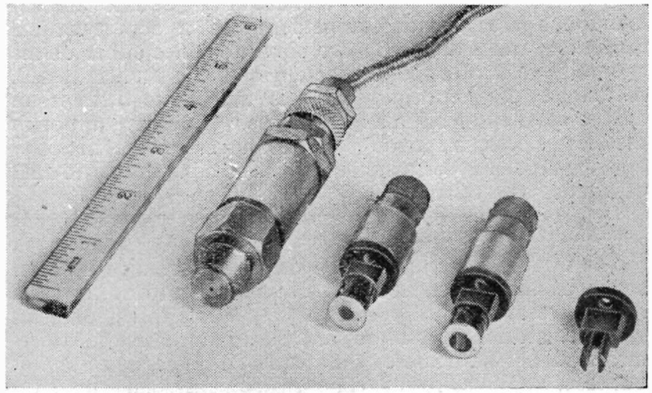


Fig. 1. Cylinder Pressure Pick-up Units

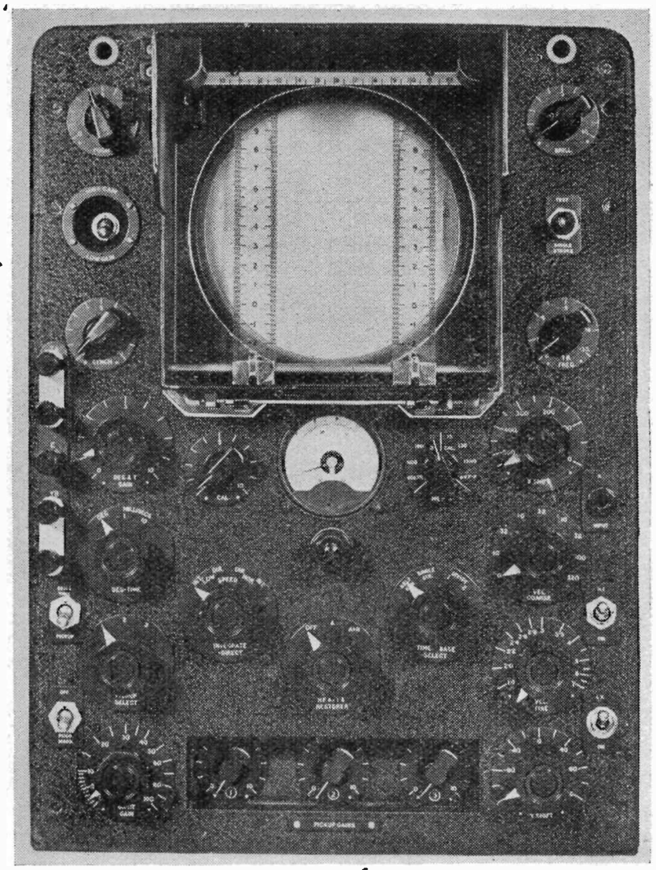
A complete cylinder-pressure unit is seen on the left and the essential magnetic unit removed from the case immediately to the right. To the right again is a newer type of unit with a double-pole arrangement to reduce time lag and consequent phase shift. The unwound pole construction is seen on the extreme right.

Such diagrams are of special value since they give the clearest indication of events in the engine cycle, and enable relatively large deflexions to be obtained for phenomena (such as the incidence of knocking) which involve sudden but quite small changes. When the more usual diagram showing pressure or mechanical deflexion at any moment is required, the E.M.FS. generated by the pick-up may be passed through an electrical integrating circuit.

The display unit illustrated in Fig. 2 provides all necessary amplifying and integrating circuits. Various mark-

Fig. 2. The Display Unit (Type F)

Showing the various controls and a 270-degree meter for calibration; a viewing hood fitted with adjustable cursors is provided. The hood may be used for attaching a camera, or a piece of tracing paper may be clipped behind it in contact with the screen.



* *Transmission Division, Standard Telephones and Cables, Ltd.*

ing devices in addition to the crank-angle base already mentioned are provided, together with a 50c/s vertical calibrator, and a divide-by-two circuit enables either of the two half-cycles of a four-stroke engine to be studied at will. A feature of the display unit is that units other than electro-magnetic pick-ups may be used, if desired, although the new electro-magnetic pick-ups have for the majority of applications a performance which is comparable to that of almost any other type.

Quantitative Measurements

The fact that one may watch the display change progressively as the engine controls are varied affords an ideal qualitative analysis of performance. While this is of great value, it is often very important that quantitative measurements should be made of the displayed diagram. For this purpose, the electro-magnetic instrument lends itself to very accurate dynamic calibration against statically measured air pressures in an air bottle. This is done by the calibrating unit operating on the same principle as the indicating pick-up units, in which a small differential disk-valve is actuated when the variable gas pressure below its diaphragm equals the steady bottle pressure above it.

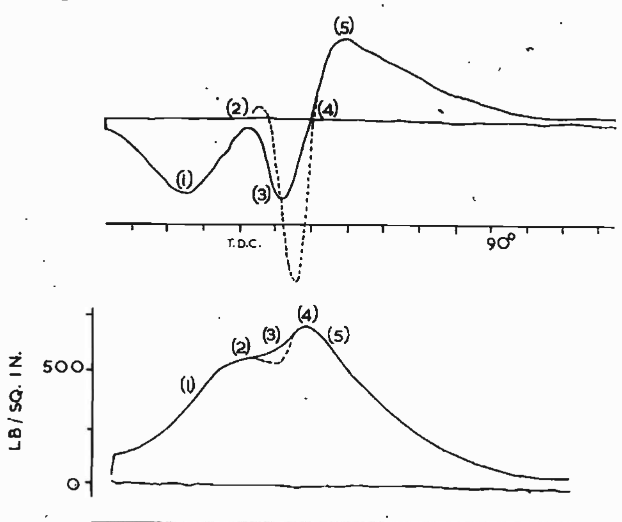


Fig. 3. Typical cylinder pressure diagrams for a 4-stroke engine

Fig. 3(a) (upper) is the rate of pressure diagram taken directly from the unit and Fig. 3(b) (lower) is the same after integration. Numbers have been added to the diagrams to indicate corresponding events.

The Use of the Indicator

The simplest and commonest application of the engine indicator is to the study of cylinder pressure diagrams. For this work, a cylinder pressure pick-up is used with a silicon-steel diaphragm capable of withstanding the highest pressure expected. Generally the diaphragm is about 1/32in. thick and has a natural resonance of about 45,000c/s; giving a total movement at its centre of the order of 0·0005in. For so-called weak spring diagrams (a reference to the old drum-type indicator) a much thinner diaphragm may be used in an adaptor so arranged that, during the heavier pressures of the compression and firing strokes, the diaphragm is held against a limit stop. The pick-up complete with diaphragm and adaptor is fitted into the cylinder head at some suitable point and connected by cable to the indicator. A Time Sweep unit fitted to the end of the shaft provides indications of crank angle and also affords both mechanical and electrical means of providing an impulse which can be used to produce a horizontal deflexion.

A typical cylinder pressure diagram is shown in Fig. 3(a). This may seem strange to those conversant only with direct pressure as opposed to rate-of-change of pressure diagrams. After integrating, the diagram assumes the more familiar form of Fig. 3(b) where numbers have been added to bring out the correspondence with Fig. 3(a). It will be seen that Fig. 3(a) is more convenient when it is wished to determine the point at which some cyclic event occurs, as for example, the beginning of combustion indicated on the diagrams by the number 2. A similar comparison is given by Figs. 4(a) and 4(b) where the incidence of knocking is displayed on both types of diagram. The degree base with 10-degree intervals is drawn beneath the diagrams and a portion of this as it would be seen on the screen appears below Fig. 4(b). The horizontal line in Fig. 3(a) represents both the suction and exhaust strokes. As an example of the wide range of the instrument, these two strokes are shown further explored in Fig. 5 which is a weak-spring diagram. Further, this diagram was taken with a calibrating unit and is of a high order of accuracy.

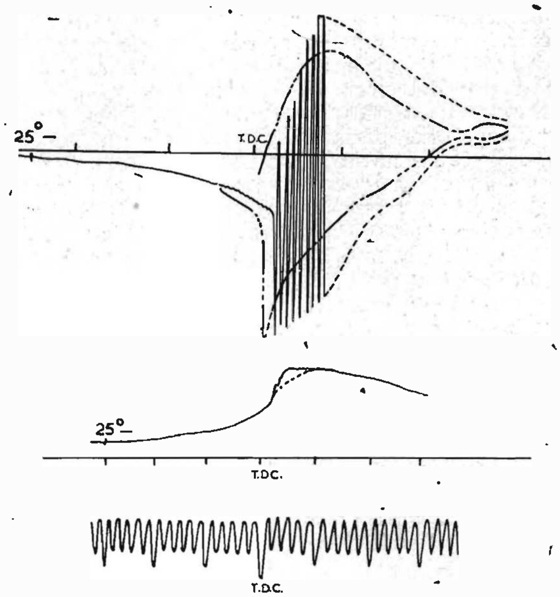


Fig. 4. Typical cylinder pressure diagram showing the effect of detonation or "knocking"

The dotted line of Fig. 4(a) shows the result of improving the fuel. Fig. 4(a) is the unintegrated diagram showing that detonation produces a vibration of high amplitude at the frequency of a sound wave backwards and forwards in the engine cylinder. The first eight periods of this wave are shown followed by dotted lines giving their average envelope. The chain dotted line was taken using a petrol of different composition but the same octane number. The amplitude of the vibrations (shown by the chain-dotted envelope) is appreciably less.

By using suitable units, diagrams may be drawn (both directly viewed or plotted by a calibrator) showing the pressure or rate-of-change of pressure of the oil in a fuel pipe.

Any moving part of an engine which can be made to vary an air gap may be indicated on the screen (see Fig 6). This shows the movement or lift of a spray valve and it is an integrated or displacement diagram showing a slight tendency to reseat after it has reached its maximum opening. As is well known, the behaviour of injection valves with varying speed and load, is of great interest in diesel engines. Qualitative examination with an electronic indicator brings out these pecularities which may include erratic jumping from cycle to cycle or hammering, i.e. several reseatings during one period of nominal lift. Bounce at the moment of closure is best examined on the rate-of-change diagram since the vibrations produced are small in magnitude, but very rapid.

A variation of the same technique can be used to show vibrations in any part of the engine framework using vibration microphones or seismic units, but it is now usually considered more useful to apply resistance strain gauges. The technique is well known and need not involve "indicating" as long as a static strain is to be measured. If, however, the cyclic variation of strains is of interest, it is a simple matter to introduce the output of any type of strain-gauge bridge into the system in place of a normal type of pick-up.

A question of great interest for all engine designers is that of torsional vibrations in shafts, which, if allowed to run near certain critical speeds, may cause them to break or, not much less serious, the bearings to be damaged. Special torsional units can be provided as adjuncts to the indicator to enable vibrations of this type to be studied.

The torsional unit consists of two concentrically mounted elements, comprising a coil system and a permanent magnet, so arranged that the inner element is driven directly by the engine shaft while the outer element is driven freely

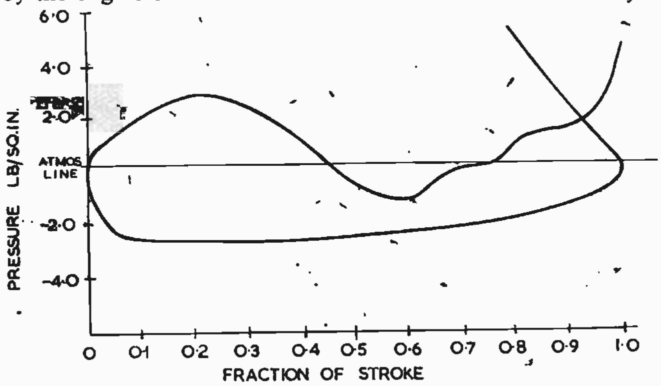


Fig. 5. A "weak-spring" diagram taken point by point using a calibrating unit and air-bottle

Only the suction and exhaust strokes appear, the other strokes being blocked off because the diaphragm of the pick-up seats when the pressure exceeds a pre-determined value.

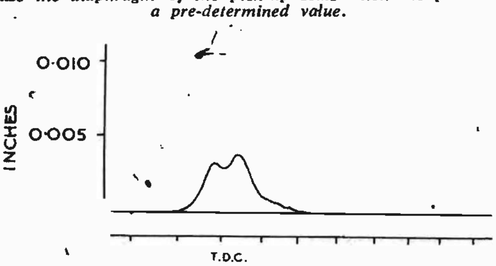


Fig. 6. A spray valve lift diagram

This is an integrated diagram and, therefore, shows displacement rather than velocity. Note a slight tendency for the valve to reseat at the top of its stroke.

through dogs so that it assumes a steady speed of rotation. Any acceleration of the shaft causes relative displacement between the coil and magnet elements and an E.M.F. will be generated which can be displayed on the screen.

The waves seen will in general be complex, but filters are available whereby an analysis of the waves into their different orders can be made and their magnitudes studied (see Fig. 7). The device can be calibrated dynamically or by attaching an arm of known length to the outer element and deflecting it suddenly between fixed stops. The resulting transient viewed through the integrating circuit, so as to give a diagram independent of the speed of deflexion, enables the whole system to be calibrated in terms of vertical deflexion per degree of shaft twist. A full analysis under various conditions of speed and load is generally compared with design expectations and quickly shows whether any dangerous modes are being excited under running conditions.

Errors

An appreciation of what an instrument will do is often best approached by considering its limitations.

It is clear, of course, that an electro-magnetic pick-up will not register static pressures since the derivative is zero. This means that it is a dynamic device like the engine to which it is applied. Where static pressures are essential, another form of unit, such as the piezo-electric, or the capacitor type, must be used.

Electrical integration is not a perfect process and will fail if attempted at too low a frequency. Therefore, a switch is provided which alters appropriately the constants of the integrating circuit for high- or low-speed engine indications. If used within its correct range, the circuit should integrate transients of simple geometrical form into figures which cannot be distinguished by eye from their expected integral counterparts—a much severer test than integrating cyclical forms.

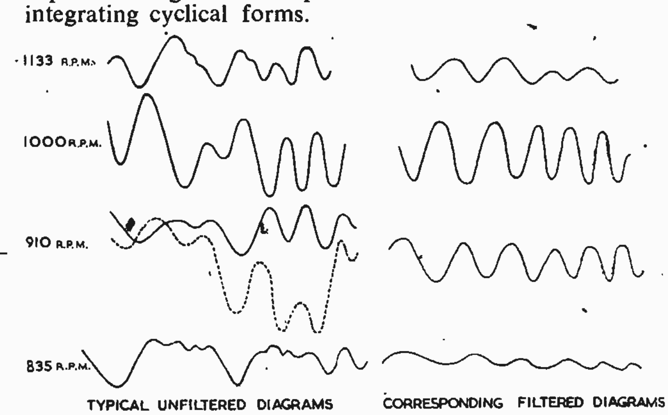


Fig. 7. Typical diagrams taken by means of the torsiograph attachments

The waves shown above are as seen on the screen with and without filtering.

The inertia of the moving parts of the pick-ups is negligible but in the older pick-ups electrical phase shift can arise and is known to cause transient distortion. In the later forms of pick-ups, however, this distortion is practically negligible.

Phenomena inside an engine are propagated at finite velocity and may be undulatory. This fact must be borne in mind when interpreting results, particularly if it is not possible to insert the pick-up at a representative point in the cylinder head. Long indicator passages are sometimes necessary and have been known to show superimposed organpipe effects on the diagrams which are difficult to disentangle. These waves, if recognised, may, of course, be filtered out, or specially tapered "quills" may be used for the passages, which will eliminate the standing wave pattern by reducing the acoustic mismatch at the ends. A short passage such as that between the cylinder and the pick-up diaphragm is an advantage as it has no noticeable effect on the diagrams, even when almost sooted up, but is useful for isolating the hot gases from the diaphragm.

Some care must be exercised, as with most electronic equipment, to avoid overloading. This was rather easy in the earlier type of instrument. The differential, for example, of a Heaviside step function is a spike of quasi-infinite amplitude, and waveforms approaching this easily overload the pre-integration stages. The new indicator is provided with a high-frequency attenuator at the input which reduces the amplitude of such spikes. After integration an inverse restorer circuit is used which exactly compensates for the original distortion at all frequencies.

Conclusion

The electronic engine indicator is a highly flexible instrument capable of giving a great variety of information with a high degree of accuracy. As will be gathered from this brief survey of its practical uses, it will be evident that, not only is it suitable for use with all types of modern high-speed engines, but, with a little ingenuity in the making of jigs and fixtures, could be adapted to novel uses. The information it yields can be examined visually, traced, or photographed for later study or permanent record.

High Frequency Heating Practice

By C. E. Eadon-Clarke,* Assoc. I.E.E.

H.F. Heating suffered in its early days from the fact that the designers of the generators were often radio engineers with little knowledge of industrial processes. This defect has now been largely overcome and the application side is being studied closely before new designs are introduced. Some firms are already specializing in complementary processes in order to present industry with the best heating method for each type of process.

The possibilities of the process can be assessed by the following points: 1. Can H.F. heating successfully do the job? 2. Has it increased production speed? 3. Does it make the most efficient use of fuel? 4. Has it permitted the use of less skilled personnel? If the answer to all these questions is in the affirmative the process will naturally have been a success, but if one or more is in the negative, then the very reverse may be the case. Therefore in this survey each question will be considered in broad outline.

1. Can it Successfully do the Job?

H.F. heating can be divided into two groups, namely Dielectric and Induction Heating. The former is applied where the material to be treated is a poor conductor of electricity, while the latter is used to heat metals.

Dielectric heating has been applied successfully to the preheating of plastic moulding materials prior to the actual moulding operation and often shows a saving in the curing time of up to 40 per cent. It has also proved invaluable in the welding together of thermoplastic sheets used so extensively for macintoshes and various fancy goods.

The process has also met with success in the furniture industry where, by the development of suitable synthetic resin glues, the setting time may be reduced to a few seconds. Normally curing times of 15 to 60 seconds are employed, since these give the operators time to load the fixtures. The industry is conservative in its approach to this new technique, but there are indications that it has now accepted it and furniture is being designed so that the process may be more easily applied.

The curing of the synthetic resin binders in foundry sand cores has been tried and hopes for the future are bright.

The cooking and re-heating of foodstuffs has not met with any real success. This failure is partly due to the non-homogeneous structure of most foods but chiefly to their relatively high conductivity. Due to this latter property arcing occurs even at quite high frequencies between the various particles of the food.

The seasoning of wood has also not proved a commercial success. The rapid heating of the wood sets up large internal strains due to the water vapour pressure which cannot be released, and so rupturing occurs. If the rate of heating is reduced to avoid this, the drying time is not vastly superior to kiln drying.

In general drying by H.F. heating has been proved to be uneconomical especially if the moisture content exceeds 15 per cent. Also most materials are difficult to dry completely by dielectric heating since they become increasingly good insulators as the moisture content is reduced. Thus the power absorbed falls off in proportion to the moisture content and although this has advantages in providing a uniformly dried product, the removal of the last few per cent of moisture is hardly possible by this method.

Induction heating has been successfully applied to most heat treatment processes. Undoubtedly where surface hardening is the requirement and the piecepart is of simple cross section the process has proved worthwhile, since full use is made of the fundamental phenomenon of induction heating, namely surface heat. But during the last two years alternative processes which are cheaper to install and run have been developed. In soldering and brazing the area to be joined has to be heated all through and the use of induction heating is fundamentally unsound because heat must be conducted away from the surface in the same way as in other heating methods. If non-ferrous materials are to be heated the rate of heating is moderately slow, while even with ferrous materials the rate of heating decreases once the Curie temperature has been reached. Thus for brazing the process is generally limited to the use of silver solders having a melting temperature below 750°C. These solders are extremely expensive at the present price of silver and industry is being forced to use brass brazing again, for which H.F. heating is not so satisfactory.

2. Has it Increased Production Speed?

The all-through heating of poor heat conductors and the almost unlimited power that can be induced into metals by H.F. heating ensures a rapid rise in temperature; and if this is the chief requirement the processing time is bound to be the minimum. In some instances the rapid rise in temperature is not, however, the only requirement, and H.F. heating should not be considered.

3. Does it Make the Most Efficient Use of Fuel?

It is in answering this question that the weakness of H.F. heating so often becomes apparent. The conversion of electrical power at supply frequency to high frequency power necessitates the use of a Rectifier, Valve Oscillator and some form of output application circuit. The efficiency of most H.F. generators into a pure resistive load is approximately 50 per cent, but the overall efficiency falls far below this in many applications, due to losses incurred in coupling the power into the load itself. Where the load is brass or copper, the overall efficiency may be as low as 25 per cent.

Comparing for a moment the relative prices per therm of various fuels, it can be seen how fantastically expensive any electrical process can be in running costs if the overall efficiency is poor.

The following prices may be taken as representative:

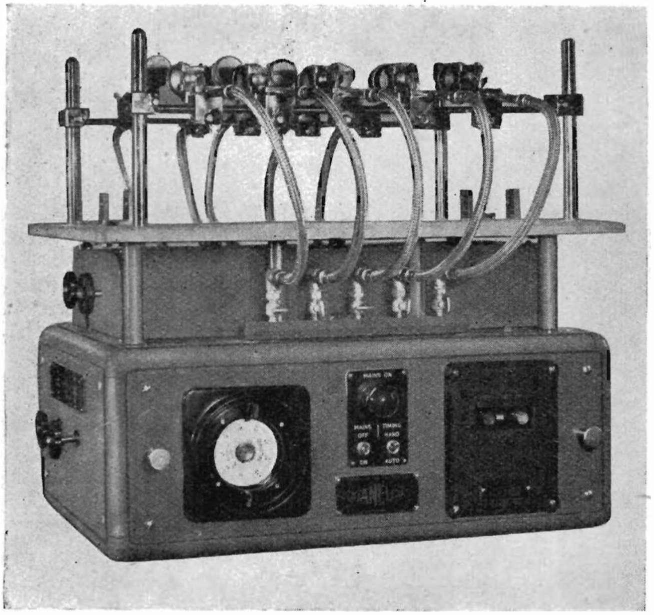
Coal	95 shillings per ton	= 4·5d. per therm.
Coke	99 „ „ „	= 4·6d. „ „
Oil	210 „ „ „	= 6d. „ „
Gas		13d. „ „
Electricity	1½d. per unit	= 44d. „ „

(based on 1kW = 3413 BTU)

Thus as a source of heat it will be seen that electricity costs approximately 3½ times as much as gas, and therefore it can only be justified if the overall efficiency of the system is reasonably high. In very many H.F. installations this is certainly not the case. How this is borne out in practice may be shown by a typical example.

It was required to braze together flanged tubular steel pipes. This was being done with a 10kVA input H.F. equipment and the time per joint was 35 seconds. Thus

* *Industrial Supplies Division, Standard Telephones and Cables Ltd.*



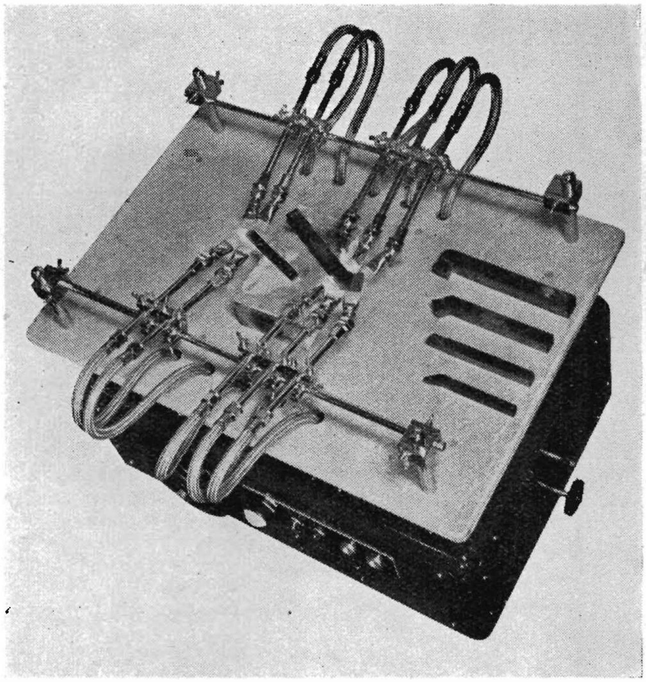


Fig. 1. The electro-gas equipment

(Above) The electric controls are on the front of the panel and the gas cocks are on the left. (Right) Brazing tungsten corbide tips for machine tools. The various ongles at which the burners can be set are shown.

the cost of electricity per joint was 1/7th of a penny. Using gas, the time was 25 seconds with a gas consumption of 120cu.ft per hour. The cost per joint is therefore 1/18th of a penny. The greatest saving is, however, achieved by the type of brazing alloy used. Since gas heating is so rapid an alloy containing considerably less silver can be used than that required for the H.F. equipment, and the saving per joint is 1½ pence.

This example clearly shows that production engineers must study their problems with great care, and every possible process should be considered before equipment is purchased. It is not enough that the process can do the operation; it must also do it at the lowest possible cost.

4. Has it Permitted the Use of Less Skilled Personnel?

The greatest benefit that H.F. heating has brought to industry has been to make it push-button conscious. By the invariable inclusion of this feature the grade of operator required for the most delicate operation is hardly more than unskilled, but quick-loading fixtures are essential so that the operator can produce a precision job. This may well be one of the expenses so frequently overlooked when assessing an application. These jigs may in some cases cost as much as the generator itself.

Alternative Processes

The study of H.F. applications has naturally aroused interest in alternative processes. The employment of electronic equipment became very popular at the end of the war due to the intense development of radar. In consequence the simpler methods were either overlooked or assumed to be outmoded. The pendulum is now swinging back as the virtues and limitations of H.F. heating have been appreciated as much by the equipment manufacturer as by the industrial user.

Infra-red heating is being used extensively for various drying operations, particularly for paint where thin films are encountered.

Strip heating which is based on the warming of thin metal strips, usually stainless steel, by the passage of alternating current at low voltage provides the furniture industry with a convenient and flexible form of heat for veneering flat or curved sections and for all glued joints within ¼in. of the surface.

Carbon resistance heating with process control has found a wide application in soft-soldering operations.

Recently introduced is a new type of equipment known as "Electro-Gas" which is proving very effective. Electrical energy is used to provide the close operational control, while gas is used as the heating medium.

The equipment is illustrated in Fig. 1 and works from the normal mains gas supply and compressed air, which are mixed by means of a special injector. An electrical supply is needed to operate a sequence of magnetic valves which control the heating and pilot flames, and also to operate the process timing circuits. The gas-air mixture is burnt in high-intensity type burners which provide either needle or thin ribbon flames, having a temperature of 1,300-1,500°C which is ideal for brazing and hardening.

The advantages of flame heating from the point of view of jigging and irregular-shaped pieceparts is immediately obvious. Jigs need not be designed with anything like the close tolerances to the heating source as in H.F. heating. Also the distance of the burner-face to the work may be over one inch, so that it is far easier to arrange for loading and the work may be continuously fed through on a light conveyor if production justifies it.

The initial cost of such an equipment is low, as are the operating costs, and the maintenance required is very small. The ordinary factory plant engineer is quite capable of doing any adjustment that might be necessary since he is well versed in the type of gas and electrical circuits employed.

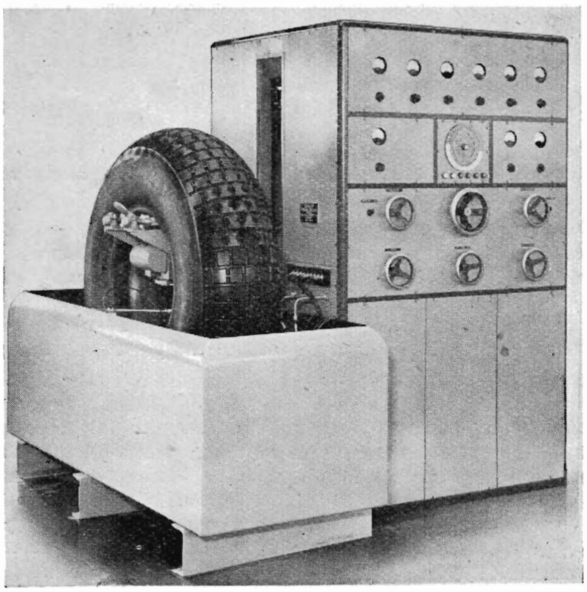
The use of H.F. heating has come to stay, and as development increases so will its application; but it is extremely unlikely that there will be any startling new applications. The process is settling down as an industrial tool and its future is likely to be steady rather than spectacular.

The author wishes to thank Standard Telephones and Cables, Ltd., for permission to publish this article and photographs.

ULTRASONIC TYRE TESTING EQUIPMENT

An instrument which embodies one of the most important applications of industrial ultrasonics, the non-destructive testing of materials, has recently been put into operation in the works of the Dunlop Rubber Co., Ltd., at Birmingham, England. The instrument, which has been developed jointly by the Dunlop Research Centre and The General Electric Co., Ltd., is designed for the production testing of aircraft and motor vehicle tyres of all types.

The method developed depends on the fact that any internal discontinuity, e.g. imperfect bonding between rubber and fabric will create an air film and that this rubber-air boundary will cause almost 100 per cent reflexion of ultrasonic waves which reach it. With new tyres a fault of this type is possible, though rare, but with used tyres it is common and may make it inadvisable to renew the treads, notwithstanding the fact that the tyre is superficially sound.



The instrument is used for tyre testing on a production basis and can detect faults having an area $\frac{1}{8}$in. by $\frac{1}{8}$in. or more. It consists of a steel cabinet which contains an ultrasonic generator and valve amplifiers, together with pneumatic handling equipment for lowering the tyres into an adjacent tank of water, where they are tested. The reason for using the water bath is that water produces a good transmission path between transmitter and receiver, together with reasonable acoustic matching with the rubber, i.e., there is negligible absorption or reflexion at the water-rubber boundary.

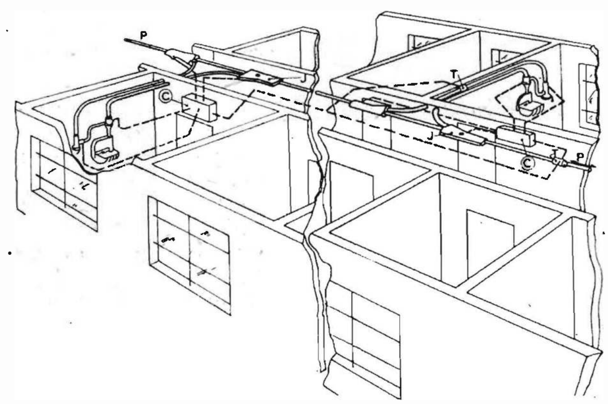
Projecting from the front of the cabinet is a pneumatically operated extensible arm, which can be given a cycle of operations to enable it to move outwards and to project beyond the tank so that a tyre can be loaded on to it. The arm then lifts the tyre, moves it inwards and lowers it on to two rollers which are mounted in the tank, above the water. The rollers can be used to revolve the tyre at speeds up to 10 R.P.M. during a test and are driven by an $\frac{1}{8}$-h.p. motor, through reduction gears. The reason for the speed range is that when a tyre is first immersed it is desirable to revolve it quickly for wetting purposes, and then to slow down for an ultrasonic test, and if necessary, to drop to "very slow" or "stop" for precise location of a flaw.

DIALLED DESPATCHES

In many organizations it is necessary to transfer papers or small parts from one department to another. This can be carried out by means of small containers propelled by compressed air through "pneumatic" tubes. If a number of departments are to be interconnected, however, this may necessitate a large number of separate tube circuits. Dialled Despatches is a system which has recently been introduced in this country, by J. W. Halpern and Partners, to overcome this limitation and, by its means up to forty-five "send-receive" stations can be linked together by a single conveyor tube. To achieve this an electronic selector mechanism is incorporated; this works as follows.

Each "send-receive" station is allotted a number; this may be either a single digit or a combination of two digits. On the end of each container there is a dial similar to that of a telephone and numbered from 0-9. Before the carrier is inserted into the conveyor tube the number of the station at its required destination is "dialled." This causes the carrier to emit a given tone as it travels through the conveyor tube, the tone being generated by reeds, selected by the dial, on the container.

The illustration indicates the control units, C, associated with each of the stations shown. The dotted lines converging at these points indicate the wiring connexions with the various co-operating parts and fittings that make up a station.



Part of Dialled Despatches plant, showing a single tube, P, passing through a corridor and feeding message stations in rooms on either side.

The inlet junction, J, contains an electromagnetically operated diverting arm that also serves as an air valve in such a manner that the total air flow is forced through the station by-pass if and when the arm is shifted into its alternative position. This divertor junction becomes operative whenever a carrier is received in a branch or despatched from the outgoing sending branch.

If the carrier arrives at and passes the traffic-guard and detector unit, T, (assumed to be the unit belonging to the required destination) the analyser inside the control unit is triggered by the tone emitted from the carrier and causes the divertor valve in the junction, J, to be operated, this causes the carrier to be diverted from the main transmission line, P, into the branch line and delivered into a silenced receptacle.

Special precautions are taken to prevent containers moving in the tube line from interfering with carriers being despatched from any of the station points.

The containers travel at a speed of 30ft per second and the distance between individual stations may vary between 30 and 3,000ft.

The saving of steel tubing over an orthodox system having 10 "send-receive" stations is between 65 and 75 per cent.

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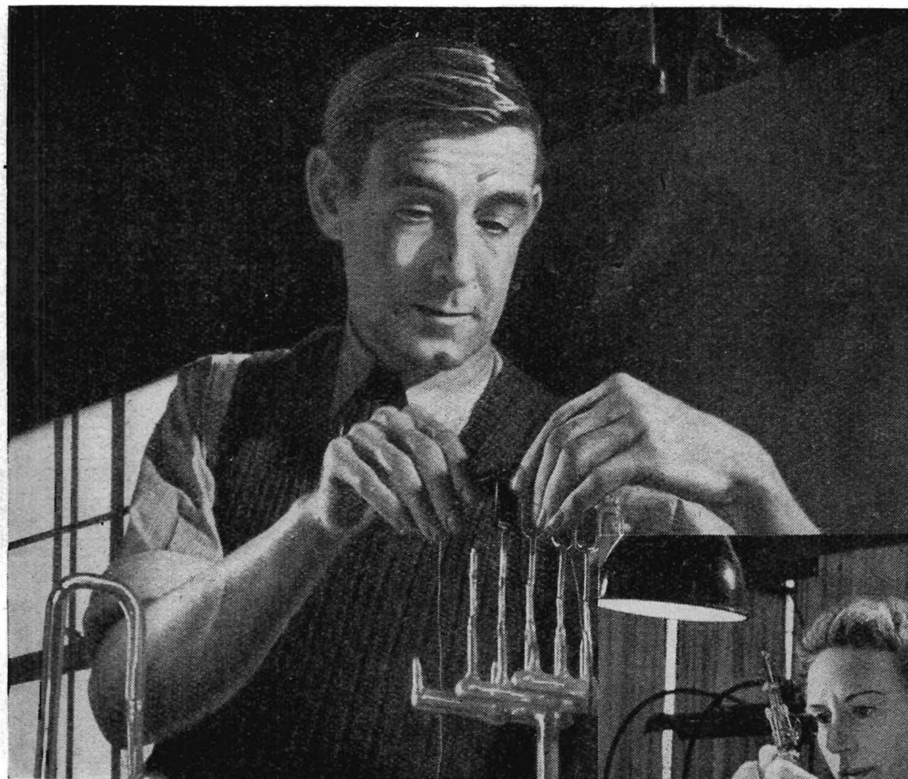

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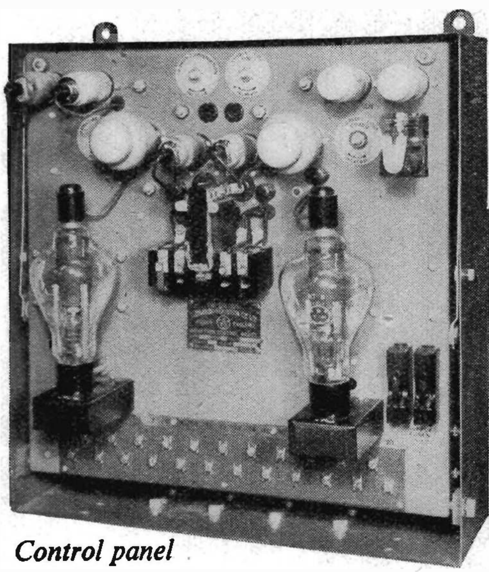

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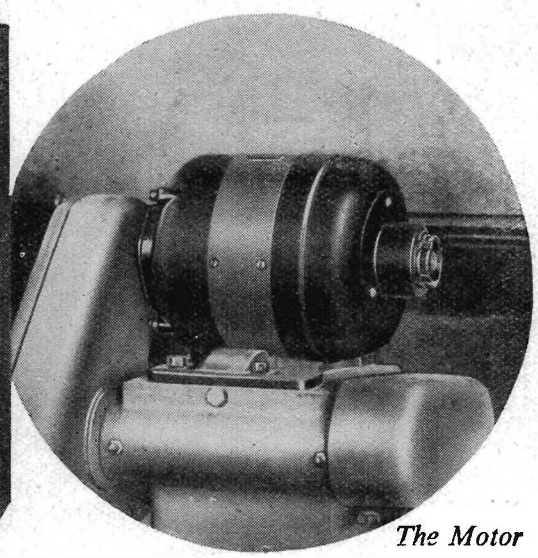

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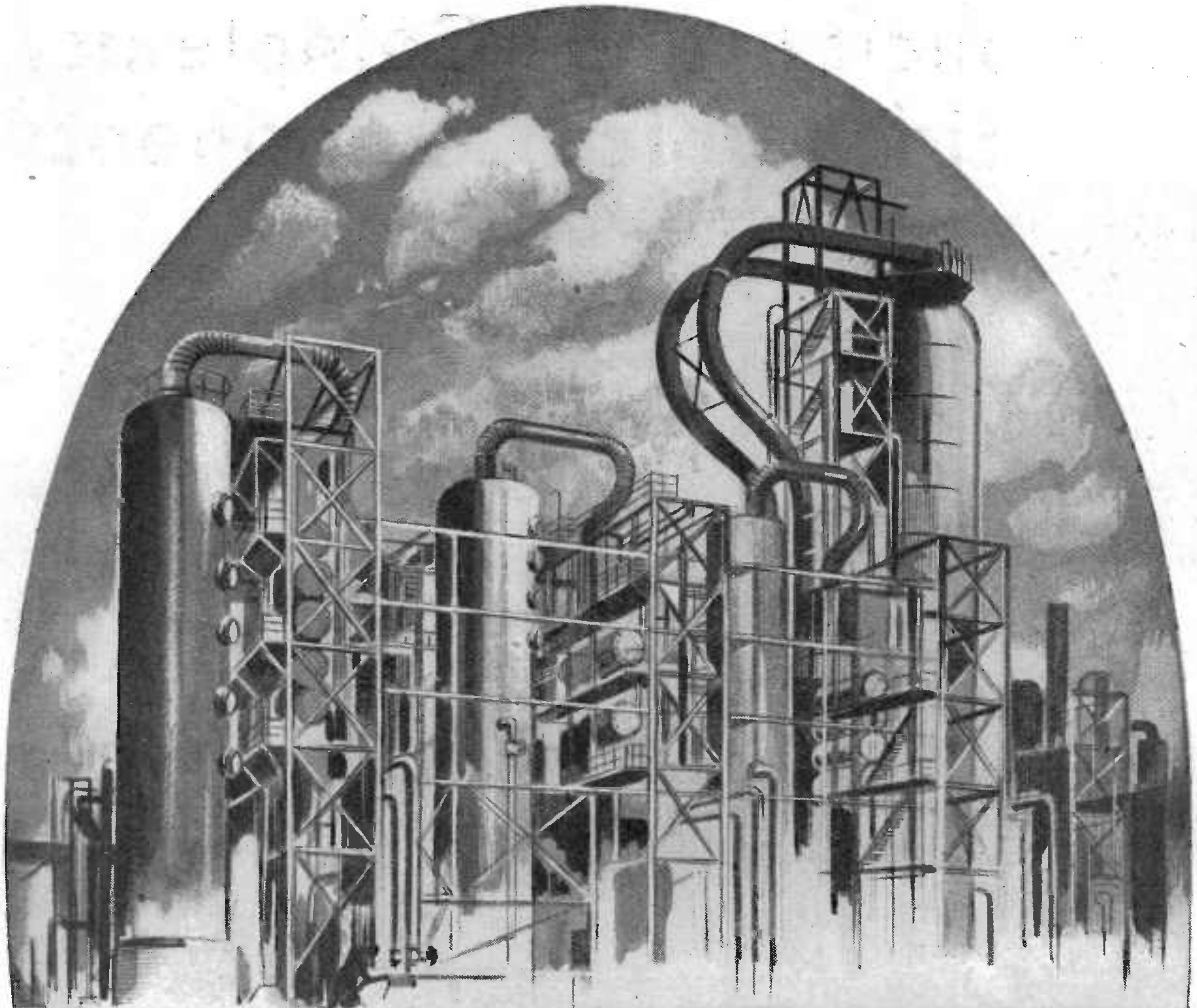


Simplicity and Complexity In Electronic Components

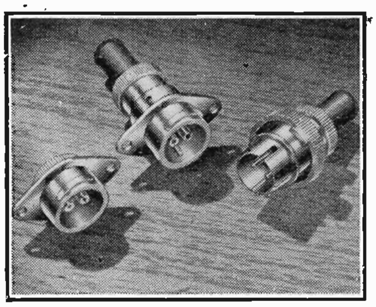
"Belling-Lee" 'B' type terminal.

Over 25 years ago, "Belling-Lee" designed their first terminal, the simplicity and effectiveness of which soon made the name "Belling-Lee" famous for the manufacture of components.

This now well-known "B" type terminal, with its insulated collar, non-removable head and non-rotating indications, is to-day virtually unchanged, and in greater demand than ever.

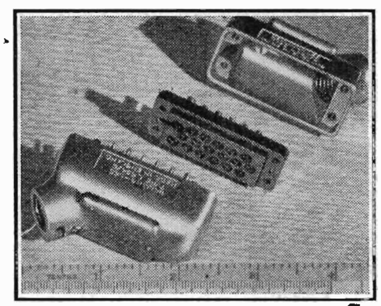
It can therefore be said that, with this comparatively simple component, "Belling-Lee" first entered the field of electronics.

The rapid progress and development of the electronic industry and its applications to the Services, created a demand for miniaturised versions of multiple connectors, both inter-chassis and cabling versions, valveholders, fuseholders, etc., designed to limits so close, as to be thought impracticable a few years ago. Design and development of such components is of necessity a somewhat lengthy and complex business. As examples of this, we quote "Screenectors," "Unitors" and B7G valveholders (illustrated), on which over 2 years' work has already been spent.

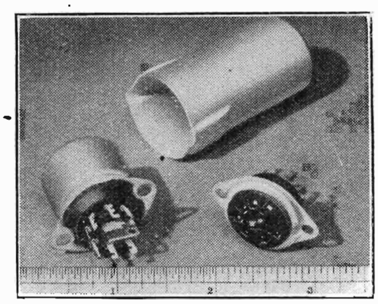


Lightweight "Screenectors" regd.

"Screenectors" are a new range of lightweight plugs and sockets, the housings of which are designed to take coaxial, 2-pole and 3-pole plug and socket assemblies. Various assemblies may be built up, *e.g.*, line connectors, flex plug and chassis socket, through chassis (bulkhead) connector, etc. Other multiple versions are in the initial development stages. "Unitors" (pronounced "unite-ors"), are the result of a Government development contract. Like any other inter-unit connector, their main purpose is to facilitate the rapid uncoupling or replacement of a sub-assembly. They are so arranged as to the non-reversible. The die-cast cover has an efficient cord grip. The holder for B7G valves is available with either fixing flange or skirt to take the standard screening cans. It complies with RC.S. 251 and has full Inter Service type approval. They are intended to fill the gap between the cheaper types and the very expensive P.T.F.E. holders, but are likely to prove too expensive for cheaper commercial receivers. The insulators are moulded from high quality nylon filled powder.



Unitors (pronounced "Unite-ors").



B7G Valveholder.

The components mentioned above, together with many more of interest to the Electronic, Electrical, and Radio industries, are fully illustrated and described in our general catalogue. Please write for this, quoting P365 ES.

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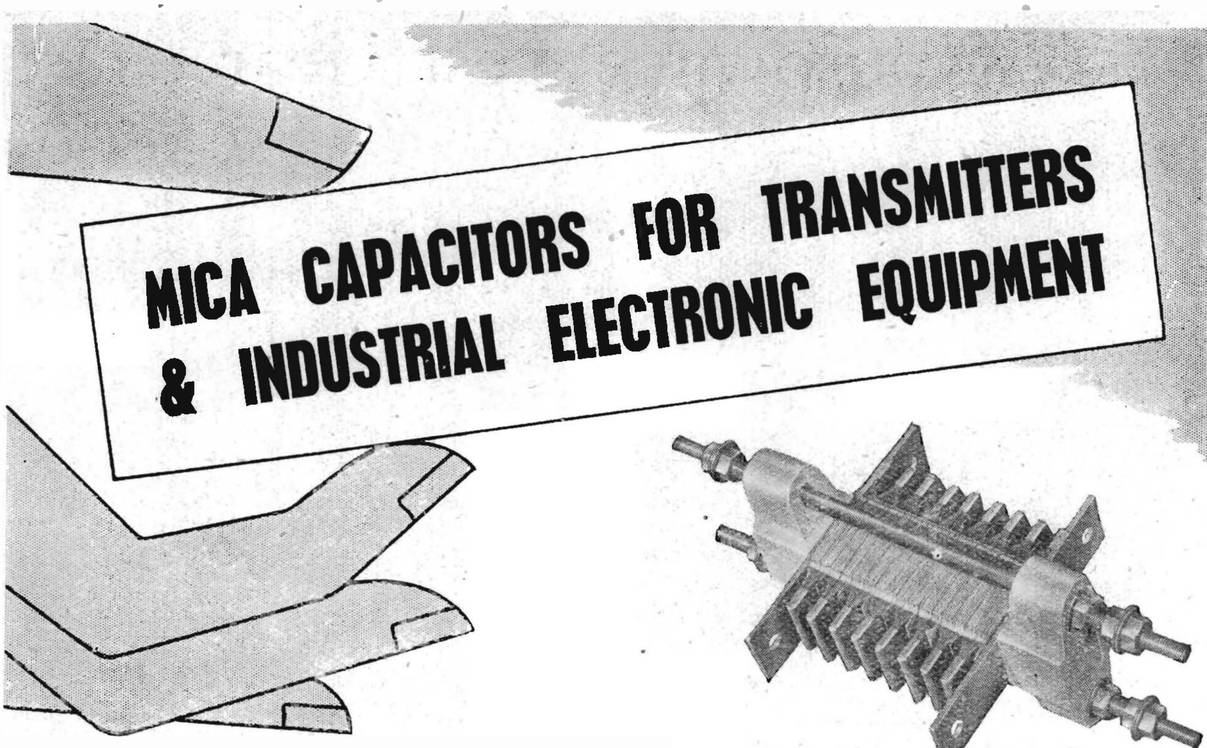
CAMBRIDGE ARTERIAL RD., ENFIELD, MIDDX., ENGLAND



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.

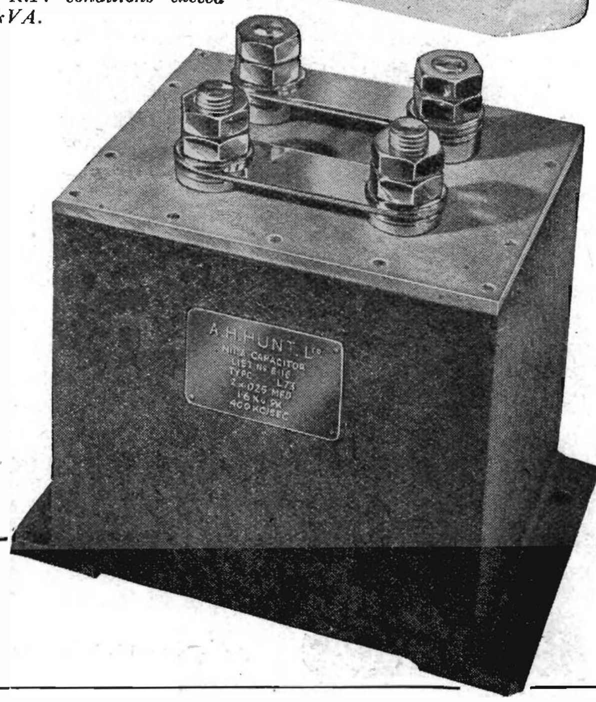
The standard range of metal tank types covers four sizes of cast aluminium containers and is extended with steel and non-ferrous tanks.

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.

OPEN CLAMP CONSTRUCTION TYPES L74 AND L75
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.



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TOROIDAL
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10-1000 WATTS
Ceramic Insulation only—and approved for Tropical conditions. Complete Ceramic Rings for strength. Approved by all Government Departments. Reasonable Delivery.
Also precision Toroidal-wound Potentiometers (including 360° of winding with up to eight tapping points) and Helical wound Potentiometers of 3600° of winding. All are available with sealed spindles and glass or ceramic terminal seats.
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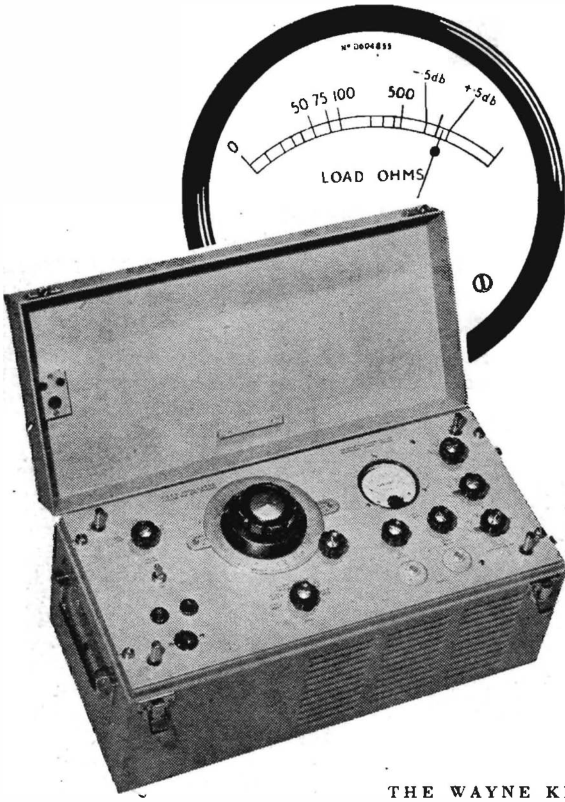

Video-Frequency Oscillator

Type 0222

7 kc/s to 8 mc/s

Outstanding features of the Wayne-Kerr 0222 Video-Frequency Oscillator are its low harmonic content and unusual stability—both of frequency and amplitude. It can, in fact, be switched to any of the six ranges between 7 kc/s and 8 mc/s with negligible change in output level. A further advantage is its special facility for indicating the modulus of the load impedance to which it is connected. This instrument is easily carried about in its transportable case, or it can be supplied for rack mounting if preferred.

Wayne Kerr

THE WAYNE KERR LABORATORIES LIMITED, NEW MALDEN, SURREY

ALL-POWER

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Semi-standard designs are available covering output voltages from 0.1 to 2,000 volts and output currents from 1mA to 10 amps.

Special Units can be made to any Specification, and although the demand for our products is continually increasing we can still offer reasonably prompt delivery.

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APPLYING ULTRASONICS TO INDUSTRIAL PROCESSES

This L.F. Ultrasonic Equipment can be used to great advantage

For the first time, Industry can apply Ultrasonics to many of its processes. This great advance is due to the development of an L.F. Ultrasonic Generator by Mullard Research Laboratories.

METALLURGICAL FIELD

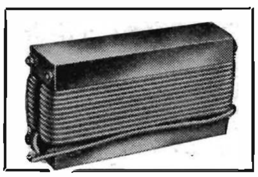
The processes to which Industry can apply the generator are numerous. There is great scope for application in the metallurgical field. This includes mixing powdered metals; mixing molten metals in alloy production; speeding up solidification of molten tin and aluminium and similar metals.

EMULSIFYING LIQUIDS

With this generator, it is also possible to emulsify various liquids more quickly and efficiently. And dispersion of particles in suspension can be carried out. Ultrasonics provide a revolutionary method of cleaning and washing, too. The photograph below shows rayon waste before and after treatment in 1% cold soap solution. Application time was 15 seconds.

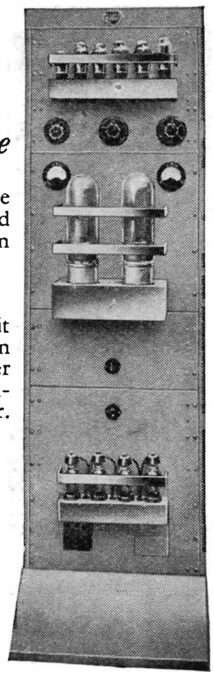
SPECIAL FEATURES

Transducer capable of handling high power per unit area. Magnetostriction head can be immersed in conductive or non-conductive liquids. Transducer designed for installation into existing plant. Simplified controls for operation by semi-skilled labour.



The robust transducer

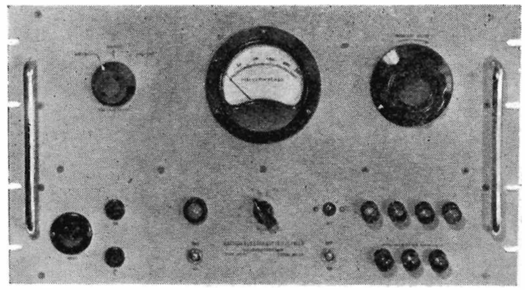
Rayon waste before and after treatment

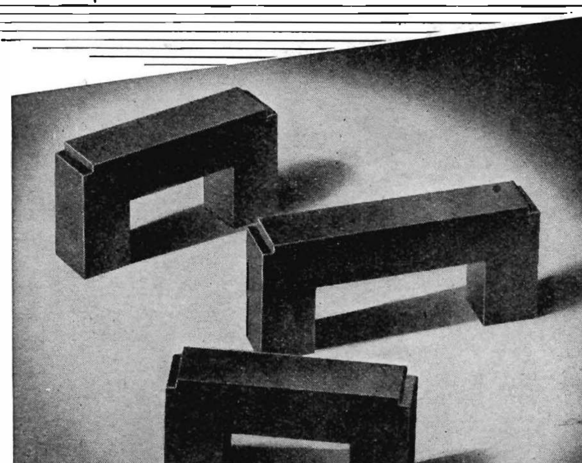


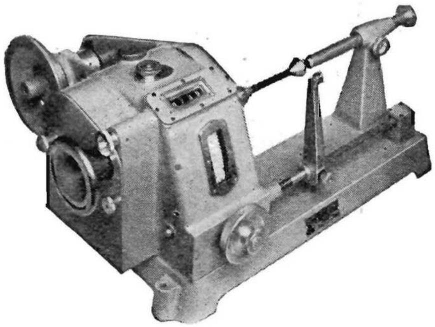
The Mullard Ultrasonic Generator, Type E.7594.

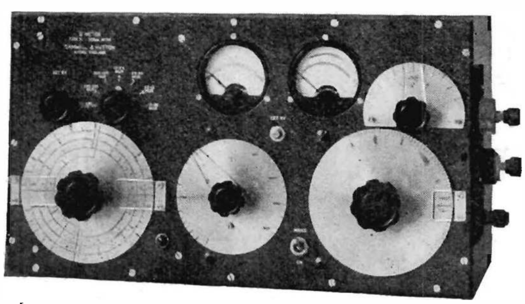
Mullard

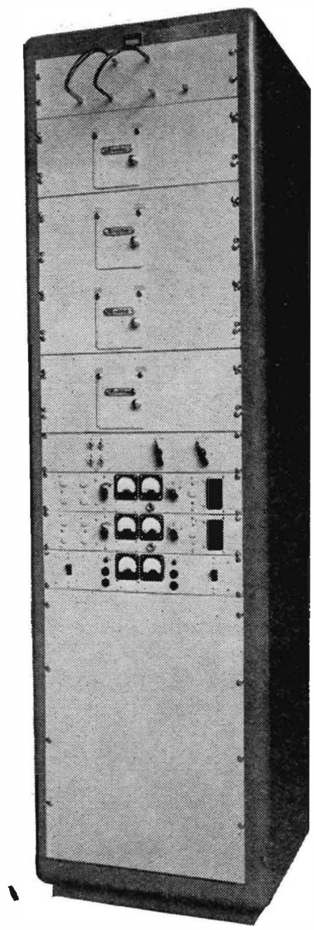
NORTHERN AGENT: F. C. Robinson & Partners, Ltd., 287, Deansgate, Manchester, 3.
MIDLAND AGENT: Hadley Sound Equipments, Ltd., 72, Cape Hill, Smethwick. Smethwick 0977.
SCOTTISH AGENT: Land, Speight & Co., Ltd., 73, Robertson Street, Glasgow, C.2.

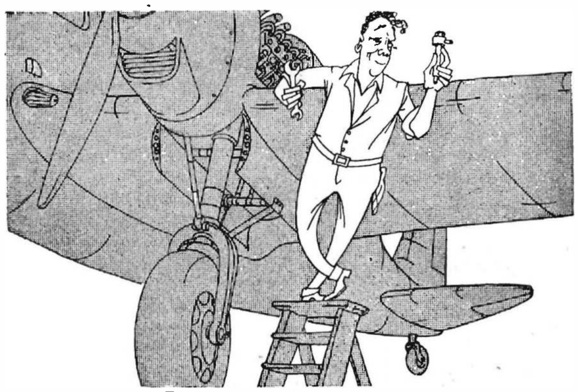


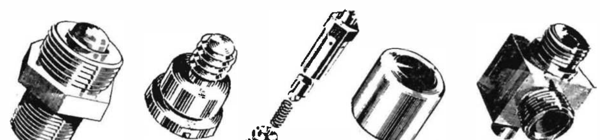


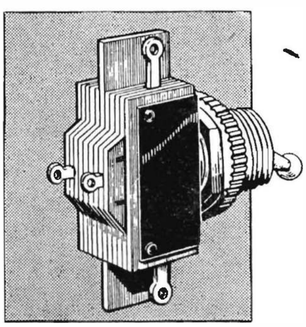


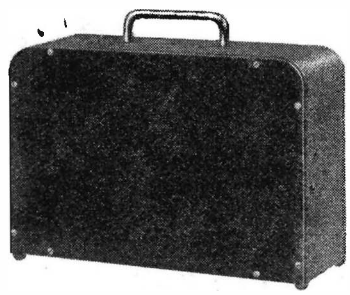












INDEX TO ADVERTISERS

Printed in Great Britain by The Press at Coombelands, Ltd., Addlestone, Surrey, for the Proprietors, Morgan Brothers (Publishers) Ltd., 28, Essex Street, Strand, W.C.2. Registered for Transmission by Canadian Magazine Post

ELECTROLYTICS for 85°C without voltage de-rating

T.C.C. introduce a new range of electrolytics with outstanding features. Independent tests at full working volts at 85°C. for 1,000 hours substantiate our claims on these condensers.

ABILITY TO WORK AT HIGH TEMPERATURES

These condensers work satisfactorily up to 85°C. at full working voltage, i.e., no de-rating is necessary.

LEAKAGE CURRENT

Exceptionally low at room temperature, with minor increase as temperature is raised.

SHELF LIFE CHARACTERISTIC

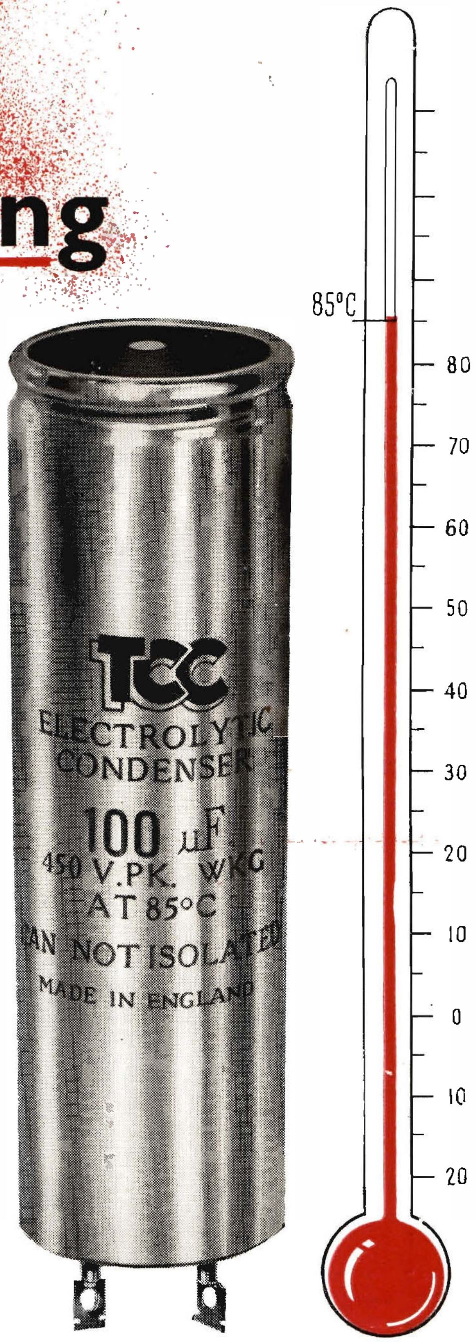
Whereas the leakage current of the normal commercial electrolytic increases when idling over a long period, that of the 85°C. construction remains relatively constant.

RIPPLE RATINGS

Because of characteristic low leakage current and ability to work at high temperatures, these condensers are capable of handling much higher ripple currents for the same size of case.

ETCHED FOIL CONSTRUCTION

Cap. µF	V. Pk. Wkg.	Dimensions In Inches. L.	Dimensions In Inches. D.	Max. Permissible Ripple m A 60°C.	Max. Permissible Ripple m A 85°C.	Type No.
8	450	1¾	¾	100	60	SCE160PE
16	450	1¾	1	175	100	SCE120PE
32	450	2¾	1	280	160	SCE122PE
60	450	2⅞	1⅜	520	300	SCE125PE
100	450	4½	1⅜	800	450	SCE126PE



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Further details of this range available on request

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