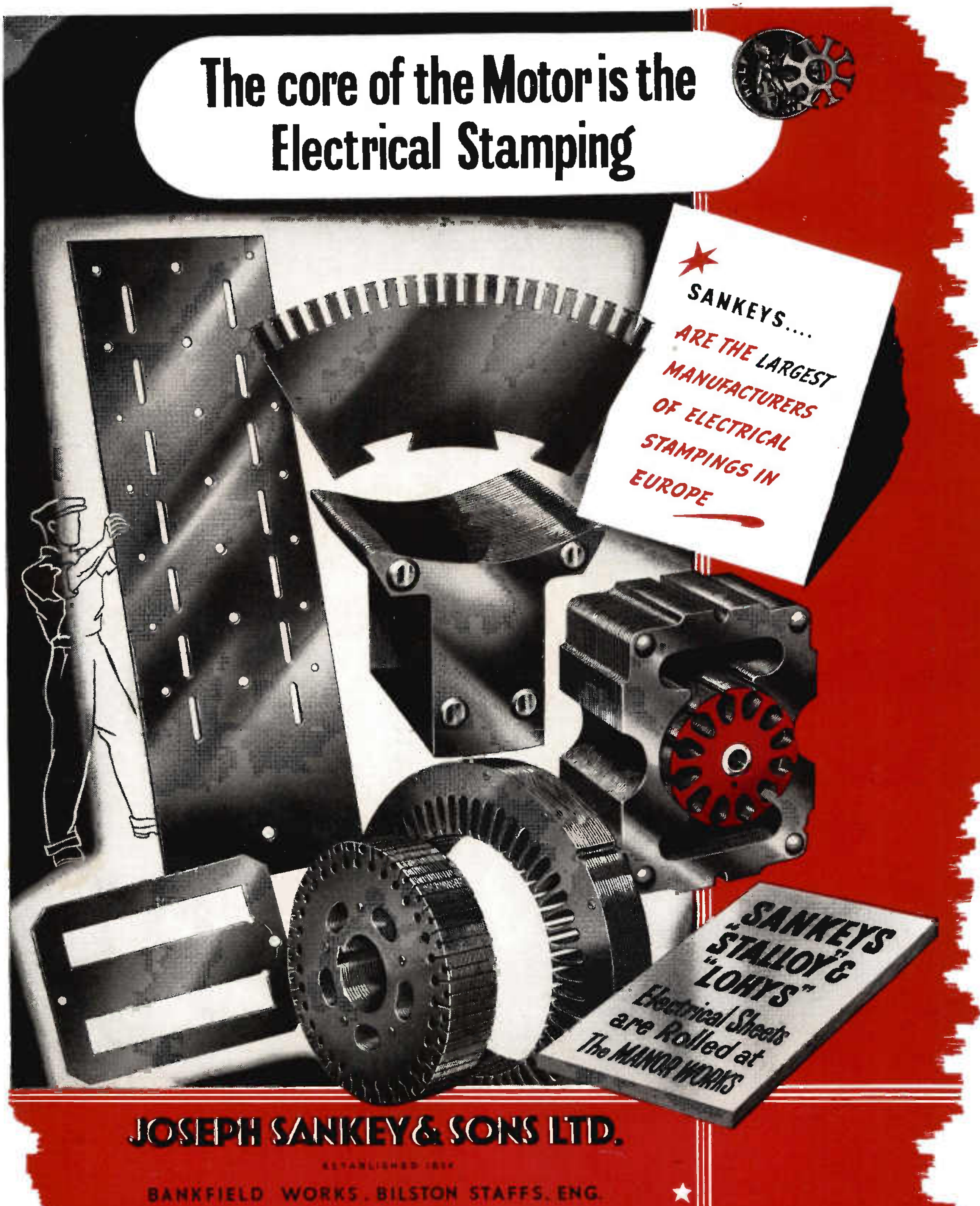
Electronic Engineering

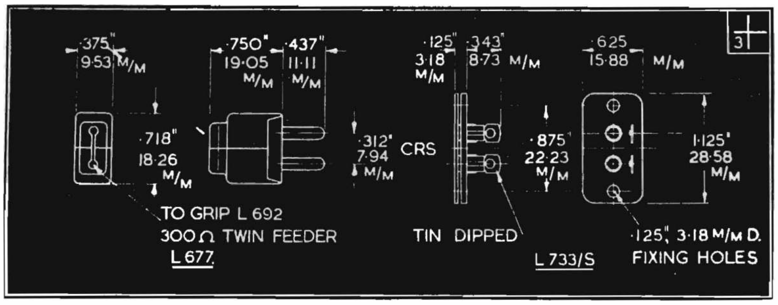
AUGUST 1951

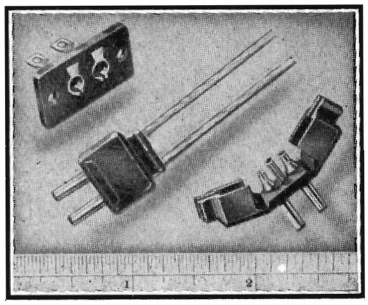
TWO SHILLINGS



The core of the Motor is the Electrical Stamping
SANKEYS.... ARE THE LARGEST MANUFACTURERS OF ELECTRICAL STAMPINGS IN EUROPE
SANKEYS "STALLOY" & "LOHYS" Electrical Sheets are Rolled at The MANOR WORKS
JOSEPH SANKEY & SONS LTD.
BANKFIELD WORKS. BILSTON STAFFS. ENG.
TELEGRAMS · SANKEY · BILSTON
LONDON OFFICES ULSTER CHAMBERS 168 REGENT STREET W.1

The "Belling-Lee" page for Engineers





TWIN FEEDER PLUG

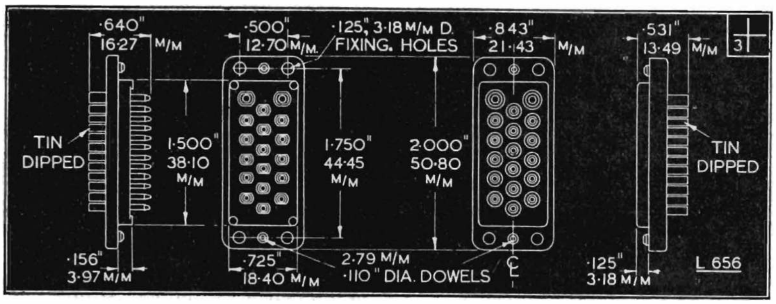
LIST NUMBERS

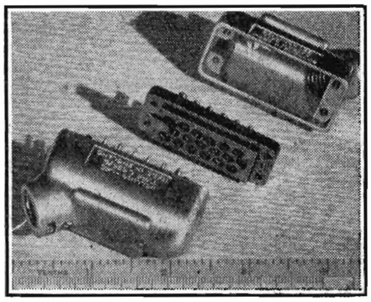
L.677	Twin Feeder Plug
L.733/S	Outlet Socket
L.739	Outlet Box

This is a newly designed plug for use with 300 ohm unscreened twin ribbon feeder (" Belling-Lee " L.692) as used in short-wave transmission and reception.

The method of loading is particularly simple ; the conductors are pinched in the spills on the solid pins, and the " butterfly " type moulding, when folded over the feeder, retains its closed position by means of special slots which grip the feeder.

This plug can be used with outlet socket L.733/S and outlet box L.739.





UNITORS (PRONOUNCED "UNITE-ORS")

LIST NUMBERS

L.653/P & S	4 Pins
L.654/P & S	8 Pins
L.655/P & S	12 Pins
L.656/P & S	18 Pins
L.656/C	Cover for above
L.657/P & S	25 Pins

Like any other inter-unit connector, the main purpose is to facilitate the uncoupling or replacement of a sub-assembly for servicing or replacement in event of failure.

The insulant is moulded from a moisture and tracking resisting nylon-filled phenolic material. There is no metal surround, a four-hole fixing flange being incorporated in the moulding together with two locating dowels, except in the case of the four-in-line model, when two-hole fixing is provided, and no dowels.

Meet us at THE RADIO SHOW EARLS COURT LONDON Aug. 29-Sept 8

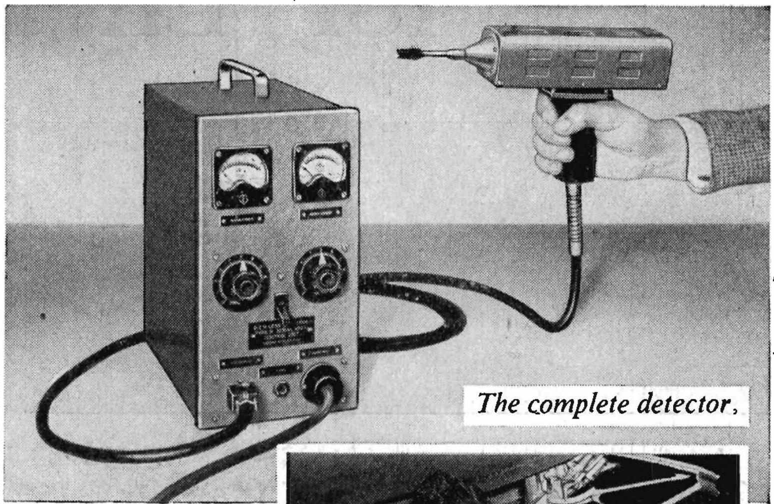
NATIONAL RADIO EXHIBITION 1951

We will be showing a comprehensive range of indoor and outdoor aerials, T.V. and broadcast, including some new designs. Also a very wide range of components including terminals, valve holders, plugs and sockets, outlet boxes, fuses and fuseholders etc., together with many new lines of interest.

BELLING & LEE LTD

CAMBRIDGE ARTERIAL RD., ENFIELD, MIDDX., ENGLAND

Electronic LEAK DETECTOR

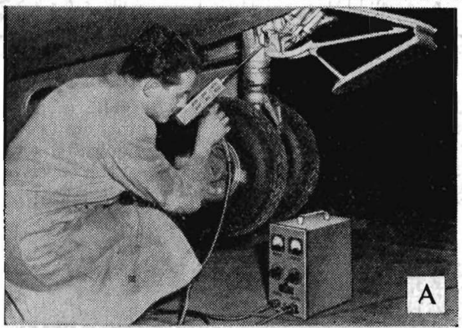


The complete detector,

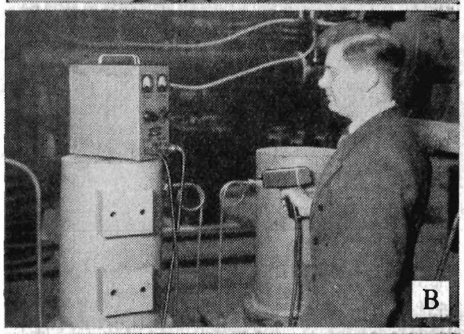
Convenient

Accurate

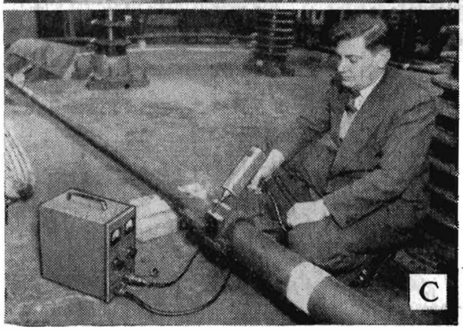
Sensitive



A



B



C

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

The detector emits, by means of a small built-in sounder, a series of clicks ; a change of frequency denotes the presence of a leak. For work in noisy surroundings headphones are available.

Illustrations show use of the detector in examining for leaks (A) *Aircraft pneumatic system* (B) *Pressure vessels* (C) *Gas-filled cable junction box.*

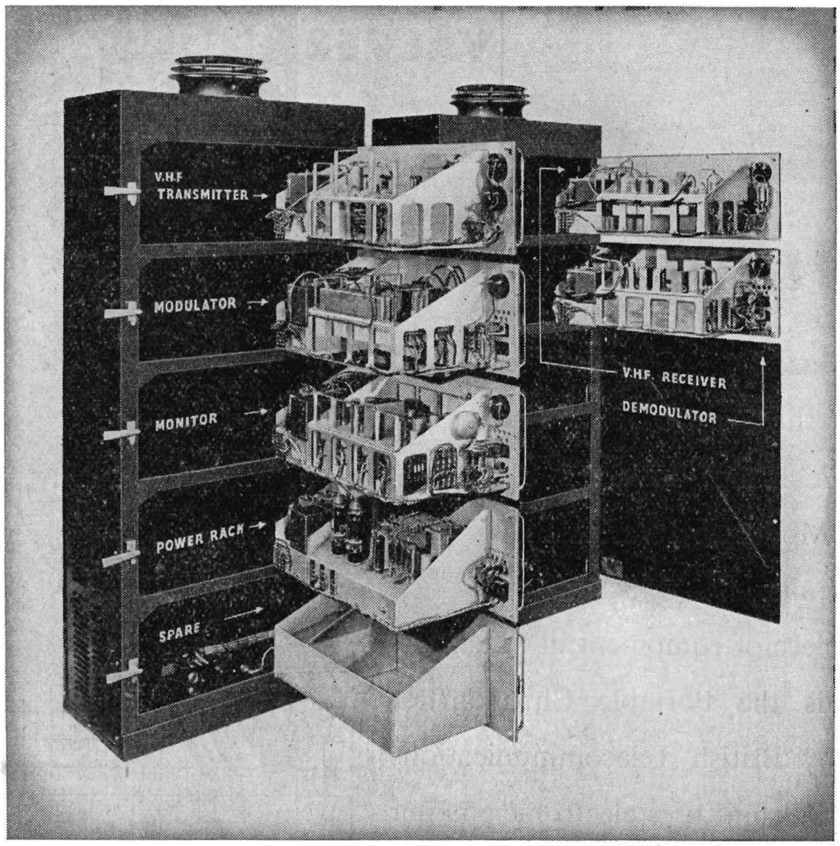
THE

BRITISH THOMSON-HOUSTON

COMPANY LIMITED, RUGBY, ENGLAND

Member of the AEI group of companies

A 4292



RADIO TRANSMISSION

OF INTERNATIONAL 12 CHANNEL CARRIER GROUPS

Where telephone lines cannot be built or are too costly, this V.H.F. FM radio system will give C.C.I.F. transmission standards for 12 channel telephone groups over a single link up to 40-50 miles long. Radio relay stations are available to extend links up to several hundred miles. Each main unit comprises a number of sub-units which are quickly replaced by spare sub-units when faults occur. The frequency ranges are from 40-90 Mc/s or 150-200 Mc/s.

AUTOMATIC TELEPHONE & ELECTRIC CO. LTD.

(Radio and Transmission Division)

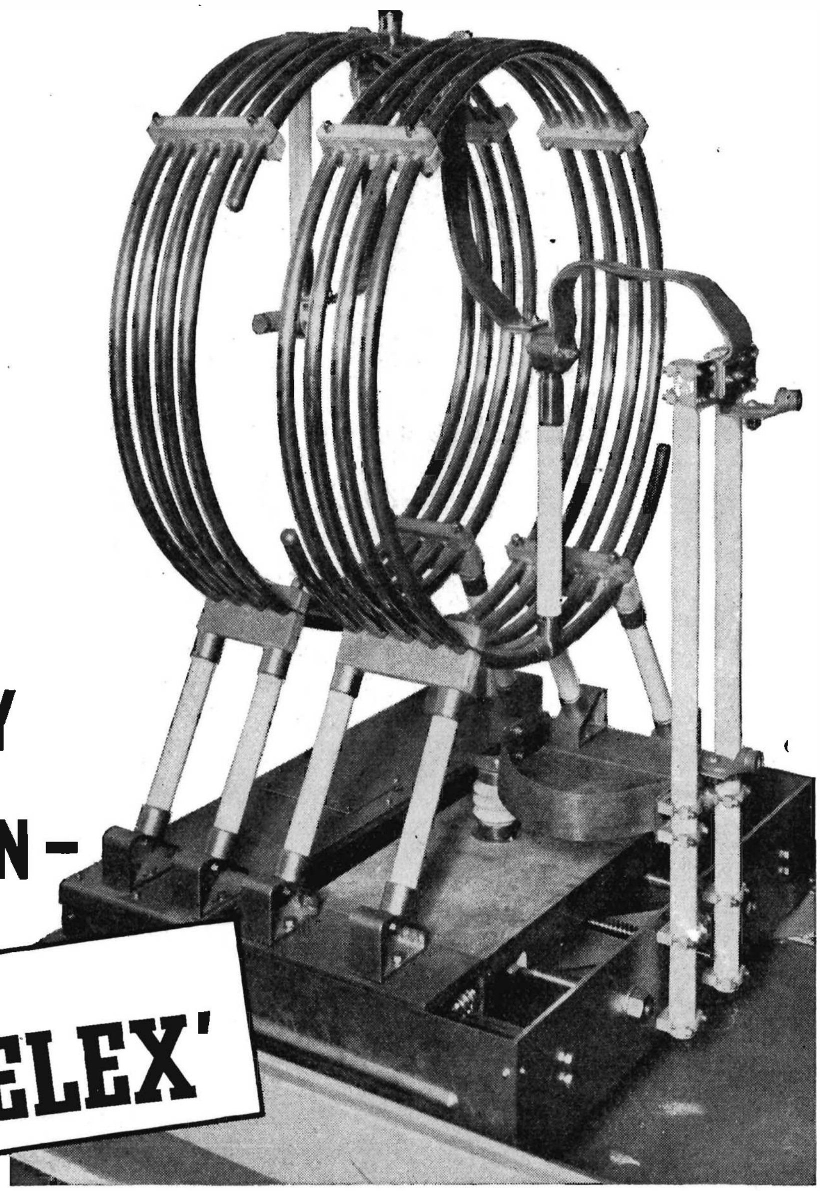
STROWGER HOUSE · ARUNDEL STREET · LONDON · W.C.2

Telephone: TEMple Bar 9262 *Cablegrams: Strowgerex, London*

A14161/B107

FOR HIGH-FREQUENCY INSULATION—

— specify 'FREQUELEX'



Photograph by permission of the Standard Telephone & Cables Ltd.

The Coupling Coil shown is supported by our "FREQUELEX" Ceramic Rods, and forms part of a 200 KW. Radio Transmitter.

This is only one of many applications where Rods made to close limits are required.

We specialise in the manufacture of Ceramic Rods and Tubes of various sections in several classes of materials over wide dimensional ranges.

The principal materials are :

1. **Porcelain for general insulation.**
2. **Frequelex for High Frequency insulation.**
3. **Permalex and Templex for Capacitors :**

The degree of accuracy depends on the size of the Rod or Tube, but the standard degree of accuracy is outlined in the Inter-Service Component Manufacturers' Council—Panel R Specification embodied in our Catalogue of Radio Frequency Ceramics, copy of which will be sent on request.

Large Rods up to 44" long and 1¼" square are used as supports for Tuning Coils, etc.

We shall be pleased to have your enquiries for all sizes of Tubes and Rods. Prompt deliveries can be given for most sizes.

TRADE MARK

Bullers LOW LOSS CERAMICS

BULLERS LIMITED, 6 Laurence Pountney Hill, E.C.4. Phone: MANsion House 9971 (3 lines). Grams: 'Bullers, Cannon, London'

BL3

...Although we do not usually boast about our achievements we do feel rather proud at the number of Cintel products chosen for the Festival! These are:-

INDUSTRIAL ELECTRONIC METAL DETECTOR (*KELVIN HALL, GLASGOW*)

MICROSECOND COUNTER CHRONOMETER (*LAND TRAVELLING EXHIBITION*)

UNIVERSAL VALVE TESTER (*POWER AND PRODUCTION PAVILION*)

MICROSECOND COUNTER CHRONOMETER (*DOME OF DISCOVERY*)

LARGE SCREEN TELEVISION EQUIPMENT (*THE TELEKINEMA*)

SELECTION OF CATHODE RAY TUBES (*TRANSPORT AND COMMUNICATIONS PAVILION*)

SELECTION OF PHOTO-ELECTRIC CELLS (*TRANSPORT AND COMMUNICATIONS PAVILION*)

GEIGER-MÜLLER TUBES (*SCIENCE MUSEUM EXHIBITION*)

Incidentally, all the Radar equipment at the South Bank employs a Cintel Cathode Ray Tube

CINEMA-TELEVISION LIMITED

A Company within the J. Arthur Rank Organisation

WORSLEY BRIDGE ROAD · LONDON · SE 26

Telephone: HIThe Green 4600

CINTEL

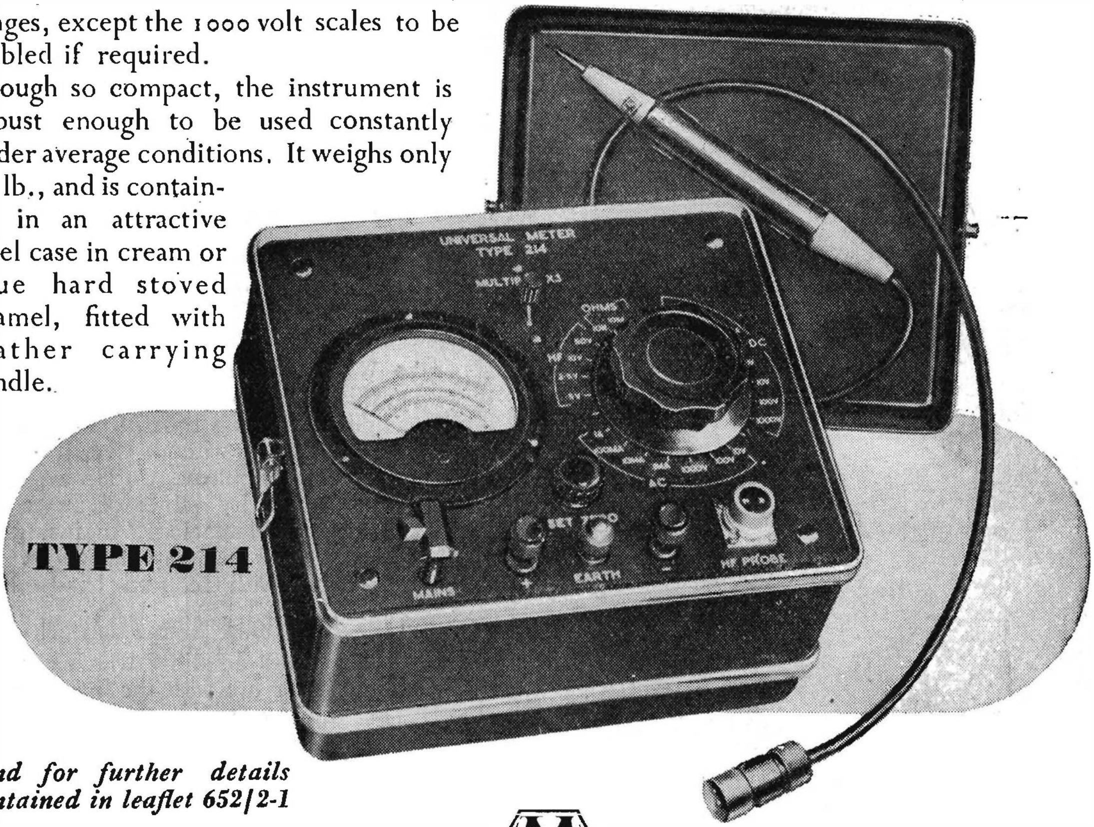
REGISTERED TRADE MARK

An entirely new development . . .

THE METROVICK UNIVERSAL METER

This latest Metrovick product in the field of electronics gives the Electronic and Radio Engineer all he needs in a multi-range instrument for the measurement of current, resistance and voltage. In addition, provision for R.F. Voltages is made by the inclusion of a probe which employs a diode valve for rectification. All sections give indication on the same moving coil instrument, and a multiplier switch enables all the A.C. and D.C. ranges, except the 1000 volt scales to be trebled if required.

Though so compact, the instrument is robust enough to be used constantly under average conditions. It weighs only 17 lb., and is contained in an attractive steel case in cream or blue hard stoved enamel, fitted with leather carrying handle.



Send for further details contained in leaflet 652/2-1

METROPOLITAN-VICKERS ELECTRICAL CO. LTD.

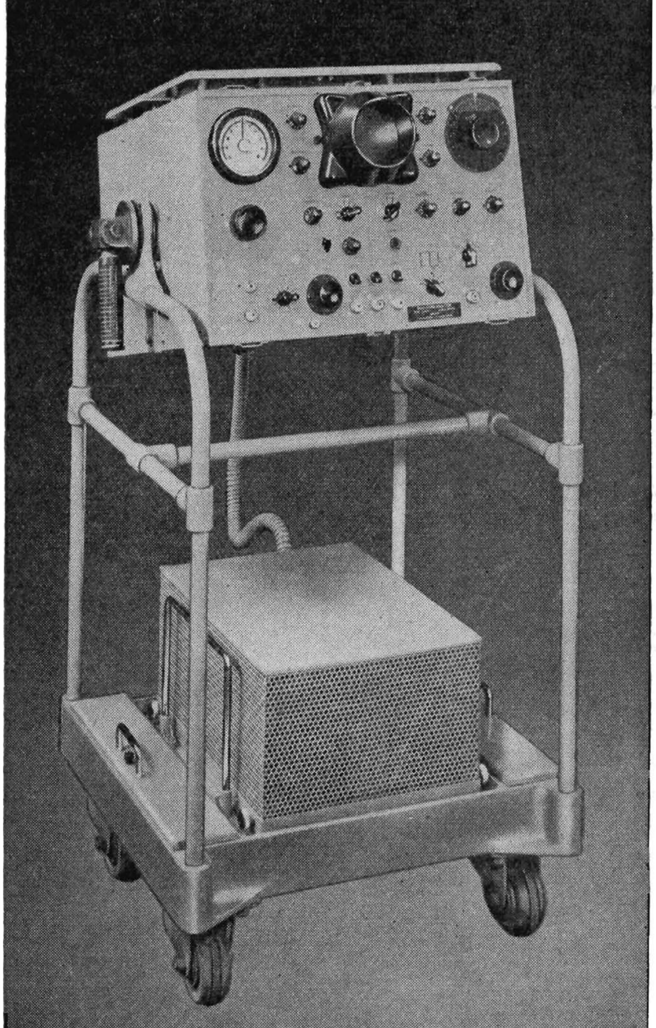
TRAFFORD PARK, MANCHESTER 17

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

R/E.901

E·M·I

WAVEFORM MONITOR



TYPE 3794

An instrument designed to meet television and radar test and research requirements with comprehensive facilities for the intimate study and precise measurement of complex waveforms.

OUTSTANDING FEATURES:

- Direct measurement of A.C., D.C. or mixed voltages from 0.05 to 500.
- Dual input facilities with signal gating.
- Direct time measurement from 0.1 μs. to 50 ms., with an effective horizontal trace length variable to 50 cms.
- When switched to the high fidelity positions the wide band vertical axis amplifier shows a time of rise of 0.07 micro seconds without overshoot on steep fronted pulses. Under this condition sensitivity values of up to 12 mm/v are obtainable. An increased sensitivity of up to 120 mm/v is obtainable with reduced bandwidth.

TYPE 5443 GAIN AND DELAY UNIT

A wide band amplifier which can be supplied for use with the Type 3794. This unit effectively increases the available high fidelity vertical deflection sensitivity by a ratio of 5 : 1 and imposes a 1 micro second delay on the displayed waveform.

For further details apply to

E.M.I. FACTORIES LTD.

HAYES · MIDDLESEX

TRADE MARK OF ELECTRIC & MUSICAL INDUSTRIES LTD.
E·M·I FACTORIES LTD · HAYES · MIDDX

E199

RESEARCH ENGINEERS. Age 25-35. Applicants should be of Degree standard, preferably with Communications training and sound mathematical background. The work is experimental and is concerned with various problems in electronics and acoustics. Application stating technical qualifications, practical experience and salary required should be addressed, in confidence, to the Personnel Department, Kelvin and Hughes Ltd., New North Road, Barkingside, Essex. W 2000

RESEARCH PHYSICIST required by Crompton Parkinson Ltd. for work in their Guiseley Lamp Laboratories. Good Honours Degree with post graduate research Degree or equivalent research experience. Applicants preferably should have an interest in gas discharge phenomena with knowledge of vacuum technique. The appointment will carry a good salary, commensurate with qualifications and experience of person appointed, and offers attractive prospects for a progressive career. Superannuation scheme. Send full particulars of training and experience to Ref. GLD, Crompton Parkinson Ltd., Guiseley, Yorkshire. W 2016

SALES MANAGER required by large long-established Engineering Company. Must have first-class technical knowledge, preferably with University Degree in Electrical Engineering. Extensive experience of Electronics essential. Position offers wide scope for really live man possessing initiative and sales ability of high order. Apply giving full details of age, education and positions held to Box No. W 2002.

STATISTICIAN/PHYSICIST required to be responsible for statistical methods applied to chemical, physical and metallurgical problems in electronic valve development. Must be over 21 years of age and possessing an Honours Degree in Statistics or Physics with Statistics. Salary in accordance with experience and qualifications. Write giving full details to Box No. W 2009.

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

TECHNICAL ASSISTANTS, Age 20-30. Applicants should have 3 years workshop experience and either Higher National Certificate or City and Guilds Radio Communications Grade 3. The work involves—Initial experiments: Prototype construction and testing, including sea tria's: Elimination of production troubles. Application stating technical qualifications, practical experience and salary required should be addressed, in confidence, to the Personnel Department, Kelvin and Hughes Ltd., New North Road, Barkingside, Essex. W 2001

TECHNICAL ASSISTANT for vibration research on Aero Engines. Specific experience of this work not essential if well qualified to undertake experimental investigations. Write, stating age, qualifications and previous experience to: The Personnel Officer, The de Havilland Engine Co., Ltd., Stag Lane, Edgware, Middlesex. W 2010.

TEST GEAR DESIGN and development engineers required in the test gear department of large radio manufacturer in London area. Applicants must have sound theoretical knowledge and experience in the development of test gear for radio, television or other electronic equipment. The positions are senior ones and are permanent and progressive. Please state full details to Box No. W 2997.

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

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

THE SUPERMARINE WORKS of Vickers-Armstrongs Ltd., at their Winchester Design Offices require Instrumentation Engineers for interesting work on high speed aeroplanes. Qualifications preferred:- Engineering Degree with knowledge of Electronics, and practical workshop experience. Apply Personnel Department, Hursley Park, Near Winchester. W 2031

VACUUM PHYSICS LABORATORY requires engineers or physicists experienced in development of special valves for radar applications at microwave frequencies, particularly magnetrons, TR cells or klystrons. Openings include senior positions for suitable applicants offering good opportunities for advancement. Apply quoting "VPL" and give full details of training, qualifications and experience and salary expected, to the Personnel Office, Ferranti Ltd., Ferry Road, Edinburgh. W 2995

WANTED a graduate in Physics, Chemistry or Electrical Engineering, or equivalent, to be trained in the Capacitor Laboratory on the development of new materials and the exploitation of new manufacturing techniques. No previous experience is necessary and there are excellent prospects of advancement. Apply to the Personnel Department, Standard Telephones and Cables Ltd., North Woolwich, stating age, qualifications and salary required. W 2023

SITUATION WANTED

JUNIOR Electronic Development Engineer desires employment in W. or S.W. England. Partly qualified. 2½ years experience of L.F. work, Servos. Box No. W 1337.

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

CRYSTAL SET COMPONENTS. Germanium and Crystal Diodes. Permanent and catswhisker detectors and crystals. Coils—tuning condensers — headphones — complete receivers. Lists on application. British Distributing Co., 66 High Street, London, N.8. W 1319

FIRST BOOK about transmitters "Radio Communication Transmitters" by J. J. Hupert. Prof. de Paul University, Chicago, USA, published by ATA Scientific Progress Ltd., 19, Effra Road, S.W.2, price, 24s. W 133

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

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

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

TELEVISION. 6-12/28; 3/31—2/32 bound. Tel: & Sht: Wave Wld: 2/35—12/39. JNL: TEL: SOC: 9 Nos. '35—'40. Television today 2 vols. The lot 35s. D. Smith, 92 Ifield Road, S.W.10. W 1336

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

ZIRCONIUM METAL POWDER, very pure, from London stock, "Alreco." The Almex Recovery and Refining Co. Ltd., 1-3 Robert Street, London, W.C.2. W 1332

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

WANTED

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

WANTED—quantity of mumetal stamping quality, in strips 0.625 wide, or near multiple. Overall thickness 5 thou. Top price paid. Box No. W 2013.

EDUCATIONAL

CITY AND GUILDS, (Electrical, etc.) on 'No Pass—No Fee' terms. Over 95 per cent Successes. For full details of modern courses in all branches of Electrical Technology, send for our 176-page handbook—Free and post free. B.I.E.T. (Dept. 337c), 17 Stratford Place, London, W.1. W 123

NORWOOD TECHNICAL COLLEGE, W. Norwood, London, S.E.27. Full-time, part-time day and evening courses in Radio and Television (Technology and Servicing), Radar and Line. Preparation for following examinations: C. & G. Full Technological, R.T.E.B., Amateur Transmitting Licence, P.M.G. Free Telecom. Prospectus (D) from the Secretary. (170.) W 2775

SERVICE

YOUR COPIES BOUND, handsome volumes, imit. Blue Leather, Gold Lettering, 10s. 6d. each, post free. C.W.O. Jerome Alcock, Cheadle, Stoke-on-Trent. W 1272

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

METALWORK. All types cabinets, chassis, racks, etc., to your own specifications. Write Dept. "T," Philpott's Metal Works, Ltd., Chapman Street, Loughborough. W 2731

ELECTRONIC ENGINEERING or Physicist with practical experience in production and testing of electronic equipment required to organize a new section. Technical qualifications desirable. Previous experience essential. Minimum age 30. Salary £600-£750. Apply: Nash and Thompson Ltd., Oakcroft Road, Tolworth, Surrey. W 1317

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

ELECTRONIC ENGINEER. Applications are invited for the post of development engineer (West London Area). Experience on Radar, Television or similar pulse techniques would be an advantage, and special consideration will be given to applicants with B.Sc. Degree or H.N.C. Salary would be determined by qualifications and experience. Apply to Chief Engineer Box No. W 2015.

ELECTRONIC ENGINEER required with sound knowledge and experience in design and manufacture. Good prospects in modern West Country factory. Send full details to Box No. W 2957.

ELECTRONIC ENGINEERS, age 22-30 for aircraft instrument firm for development laboratory, in Guildford area. Applicants should possess a Degree or National Certificate in electrical engineering and preferably have some experience in electronics and/or electrical instruments. Apply stating experience, qualifications and salary required to Box No. W 2924.

ELECTRONIC TUBE Development and Manufacture. Engineers and Physicists required for progressive technical and supervisory positions in our development and manufacturing departments. Successful applicants will have exceptional opportunities for advancement in the rapidly expanding electronics industry. Qualifications: Good Degree in engineering or physics. Previous experience desired but not essential. Applicants graduating this year and free of National Service obligations will receive special consideration and, after appointment, will be given comprehensive training. Salary according to age and experience but will not be less than £425 per annum for Honours Graduates at age 21. Application should be made to Personnel Officer, Mullard Radio Valve Company Limited, New Road, Mitcham Junction, Surrey. W 2952

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

ENGINEERS to initiate and supervise the layout, construction and test of prototypes (to Ministry standards) of special electronic circuits for production. Considerable experience of similar work is essential and familiarity with miniature practice is desirable. Experience of radar circuits and technique would be an advantage. Senior engineers salaries in range £800 per annum and Juniors £600 per annum. Location special laboratory in Bedfordshire. Write, giving full details and quoting ref. 907 to Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, Westminster, S.W.1. W 2994

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—Construction Dept., The British Thomson-Houston Co., Ltd., Rugby. W 2017

ENGINEER REQUIRED, with good mathematical background and thoroughly acquainted with theory of servo-controlled mechanisms. Good Honours Degree or equivalent. Salary £450-£650 per annum. Location within 30 miles of London. Write, giving full details and quoting ref. HDD to Box No. W 2991.

FACTORY near Cardiff has vacancy for an Electronic Engineer with at least two years factory experience. Salary range £400 to £500 according to experience. Applicants should send details of Technical qualifications and experience to Box No. 173 C.R.C., 29 Hertford Street, London, W.1. W 2005

FEMALE LIBRARIAN required for E.M.I. Technical Library. Qualifications: Good general scientific background with practical experience, preferably in the field of Light Electrical Engineering, coupled with a keen interest in librarianship, though actual experience of this work is not essential. Knowledge of technical German and French would be an advantage. Age over 24 years. Please write, giving full details of experience and salary required, etc., to ED/36, E.M.I. Engineering Development Ltd., Hayes, Middlesex. W 2992

FERRANTI LTD., Moston Works, Manchester, have staff vacancies in connexion with long term Development Work on an important Radio Tele-Control Project. (I) Senior Engineers or Scientists to take charge of research and development sections. Qualifications include a good degree in Physics or Electrical Engineering and extensive past experience in charge of development work. Salary according to qualifications and experience in the range of £1,000-£1,500 per annum. Please quote reference R.S.E. (II) Engineers and Scientists for research and development work in the following fields: Radar, radio and electronic circuits, micro waves, high power centrimetric valves, vacuum and/or high voltage techniques, servo control and electro-mechanical devices. Qualifications include a good degree in Physics or Electrical Engineering or Mechanical Science, or equivalent qualifications. Previous experience is an advantage but is not essential. Salary according to qualifications and experience in the range £420-£1,000 per annum. Please quote reference R.T.E. (III) Technical Assistants for experimental work in the fields listed in (II) above. Qualifications required: a Degree or Higher National Certificate in Electrical or Mechanical Engineering or equivalent qualifications. Salary in the range of £260-£550, according to age and experience. Please quote reference R.T.A. The Company has a Staff Pension scheme, and will give housing assistance in special cases. Application forms from Mr. R. J. Hebbert, Staff Manager, Ferranti Limited, Hollinwood, Lancs. W 2970

HIGH POWER R.F. Dielectric Heating Equipment—Engineer required to supervise installation and acceptance tests. Experience on either large R.F. Heating equipments or Radio Transmitters employing water-cooled valves is essential. This position has particularly interesting prospects. Write, stating full experience, age and salary required to Radio Heaters Ltd., Wokingham, Berks. W 1333

INSTRUMENT testing and calibrating. Personnel required, male or female, to learn electrical and scientific instrument and component testing and calibrating. Good opportunity for juniors to gain experience. Interesting work, 5 day week. Apply in writing only, stating age and previous experience, if any, to:- W. Edwards and Co. (London) Ltd., Worsley Bridge Road, S.E.26. W 2024

JUNIOR ENGINEERS to assist in the design, construction and test of laboratory models of special electronic circuits, with several years experience of similar work. A knowledge of radar circuit designs and operations would be an advantage. Salary in the range of £600 per annum. Location, special laboratory in Bedfordshire. Please write giving full details and quoting ref. 815B to Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, Westminster, S.W.1. W 2989

MATHEMATICAL PHYSICIST required, with interest in applied mathematics, preferably with experience in radar and electronic problems. Good Honours Degree. Salary £450-£650 per annum. Location within 30 miles of London. Please write, giving full details and quoting Ref. DDA to Box No. W 2990.

MECHANICAL ENGINEER required. Good academic qualifications, recognised apprenticeship and some electrical knowledge essential. Experience in one or more of the following desirable:- Precision mechanical design, fire control mechanisms, servo theory, hydraulic and pneumatic servo systems, aerodynamics. Apply with full details of age, experience and salary required to the Personnel Manager, Sperry Gyroscope Company Limited, Great West Road, Brentford, Middlesex. W 2014

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

McMICHAEL RADIO LIMITED, 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 Limited, Slough, Bucks. W 2976

McMICHAEL RADIO LIMITED, 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 Limited, Slough, Bucks. W 2977

MURPHY RADIO LTD. (Electronic Division), have a number of vacancies in an expanding programme for Senior and Junior television, radio and electronic engineers. Excellent opportunities are available for candidates with engineering or physics degrees but post-graduate experience will be of particular advantage. Applications giving full particulars of training and experience should be forwarded to Personnel Dept., Murphy Radio Ltd., Welwyn Garden City. W 2034

PATENTS ENGINEER required for Patent Investigation work in connexion with Electronic circuits. Applicants must have a University Degree in Electrical Engineering (Light Current) or Physics. Some previous practical experience on Research or Design advantageous or alternatively, suitable technical experience in the Services. Write, giving age, fullest details of education and experience, together with salary required to Personnel Department (PDB), Electric and Musical Industries Limited, Hayes, Middlesex. W 2993

PHYSICISTS or Physical Chemists required for laboratory in Northamptonshire to carry out varied and interesting work on new ceramic and metallic materials. Applicants should have a good science Degree and be familiar with techniques for measuring magnetic and dielectric properties. Experience in designing radio and electronic components from these materials an advantage. Salary £450-£650 according to qualifications and experience. State full particulars to Box No. W 2925.

PROMINENT AIRCRAFT firm in Greater **London area, commencing new project of great National importance, offers unique opportunity for advancement. High salaries with monthly staff status and Pension Scheme offered to suitably qualified applicants. Electronic Engineers with 1st Class Honours Degree in Mathematics or Engineering preferably with several years' practical experience, though not essential. Apply, stating age, nationality and experience to Box Ac.5822 Samson Clarks, 57-61, Mortimer Street, W.1. W 131**

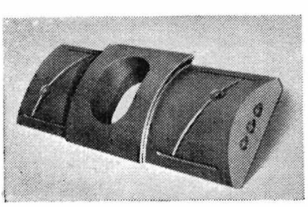
RADIO - RADAR Development Engineers urgently required, accommodation available. Applications are invited from Senior and Junior Development Engineers, preferably with experience of Radar or microwave technique, who are capable of developing equipment or components to Service Specification. Successful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

REQUIRED by large radio manufacturer in London area (1) Senior Draughtsman for communications section of the drawing office—applicants should have experience of communications equipment. (2) Draughtsman for test gear department—applicants should have experience of radio or light electrical engineering. The positions are permanent and the company has a pension fund and life assurance scheme. Apply stating full particulars of experience with age and salary required to Box No. W 2998

CLASSIFIED ANNOUNCEMENTS
continued on Page 8

Bridge...

There is little fear of burning your bridges in this case—for these Tufnol housings, built to hold copper segments making electrical contacts, combine impressive strength with the highest electrical insulation. This particular installation is in use on large excavators engaged on outcrop workings of coal and iron ore; but Tufnol is serving in countless other ways throughout the Nation's industries in their drive to maintain and increase the export trade. For Tufnol holds a unique balance between the properties of metal and hardwood, with none of the defects of either. Among other virtues, it resists chemical action, possesses high compressive, shear, and tensile strength, withstands moisture and corrosion, is light in weight, and can be quickly and accurately machined by the usual methods. Available in standard sheets, tubes, rods, bars, angles and channels, it can also be supplied in specially moulded shapes. Industry still has countless gaps which Tufnol, with its unlimited possibilities, will be able to fill.



A Tufnol slipper pad for the universal coupling of a rolling mill drive.

ONLY AN ABRIDGED VERSION

of Tufnol's remarkable properties is recorded here. The full story of Tufnol is revealed in literature which we shall be happy to send you. Let us know where your particular interests lie. If you have a NEW use for Tufnol, our Technical Staff will be glad to co-operate on it with you. Why not write TODAY?

TUFNOL

REGISTERED TRADE MARK

An ELLISON Product

TUFNOL LTD • PERRY BARR • BIRMINGHAM • 22B

251

SITUATIONS VACANT

A HOUSE (married accommodation) is available for an experienced electronics engineer capable of developing antivibration means for electronic equipment. Location is special laboratory within 50 miles of London. Starting salary £600-£800 per annum according to qualifications. Send details of qualifications and experience, mentioning ref. 850B, to Central Personnel Services, English Electric Co. Ltd., 24/30, Gillingham Street, London, S.W.1. W 2946

A HOUSE (married accommodation) is available for competent engineer able to take charge of team operating telemetry equipment in the field and in laboratory not far from London. Important defence project. Starting salary £600-£800 per annum according to qualifications. Send details of qualifications and experience, quoting ref. HHE, to Box No. W 2944.

A HOUSE (married accommodation) is available for senior radar, radio and electronics engineer to carry out development work on modern project in special English Electric Laboratory within 50 miles of London. Salary according to qualifications. Send details quoting ref. 456E to Central Personnel Services, English Electric Co. Ltd., 24/30, Gillingham Street, London, S.W.1. W 2945

A HOUSE (married accommodation) is available for Senior Electronics or Radar Engineers required to organise a ground radar system including development of certain control and monitering and supervisory circuits and displays. Special circuit engineers already available. Location in special laboratory for important defence project within 30 miles of London. Salary up to £1,200 per annum for suitable candidate. Apply quoting ref. DEF to Box No. W 2007.

A LARGE ORGANISATION of international repute invites applications from Engineers and Scientists wishing to take up commercial work in the professional electronic field. For one such vacancy, at managerial level, candidates should be between the ages of 35 and 45, and now earning not less than £1,500 p.a. Vacancies also exist for less experienced men aged about 30 with qualities likely to fit them for promotion to senior executive and managerial appointments. All candidates must have:- 1. An Engineering or Science degree. 2. Technical experience, preferably in the electronic engineering or scientific field. 3. General education and personal qualities suited for commercial work. Successful candidates will have time to familiarise themselves with the Company's products, organisation and practices. They will probably be based in the London area with occasional overseas travel and the possibility, if desired of transfer to an Associated Company in the British Commonwealth. Good prospects in various branches of an expanding business. Salary according to experience. Applications will be treated as confidential and must include age, salary required, qualifications and chronological statement of experience and appointments held. Write to Box No. W 2006.

ALL GRADES of draughtsman are required at Chelmsford and in West London by Marconi's Wireless Telegraph Co. These are permanent positions on the design and development of radio and radar equipment. Applicants should write, giving full details, and quoting ref 142E to Central Personnel Services, English Electric Co. Ltd., 24-30 Gillingham Street, Westminster, S.W.1. W 2008

AN ELECTRICAL ENGINEER required for investigation and quality control work in Radio Valves and other electronic devices. Inter B.Sc. standard or equivalent. Apply, Personnel Superintendent, The Edison Swan Electric Co., Ltd., Cosmos Works, Brimsdown, Enfield, Middlesex. W 2988

AN ENGINEER is required age 28/30 for development work in process controls specializing on application of electronics, the post is a new one and will call for the capacity to work independently. Essential qualifications are age 28/30 with Degree or Higher National Certificate in Electrical Engineering. The successful applicant will be posted in East Anglia and would be required to do a certain amount of travelling. There is a superannuation scheme entry to which is dependent upon a satisfactory probationary period. The salary offered is £680 per annum. Write giving details of qualifications and experience. Box No. W 1328.

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

APPLICATIONS are invited from Electronic Engineers of Degree standard for a small number of senior positions in an expanding Microwave laboratory of a well-known W. London firm. Development or laboratory experience is essential for work involving all applications of microwave technique. Good initial salary, dependent on qualifications and experience. Please write in confidence full particulars of experience, qualifications, salary desired, etc., to Box No. W 2035.

A SENIOR ENGINEER is required by the Midlands Industrial Electronics Department of a well known Company for design and circuit work on valve type H F. heating generators. Applicants should have good experience on this type of work or on radio transmitters. A University Degree is desirable but not essential. Please write giving full details and quoting ref. CEG, to Box No. W 2020.

ASSISTANTS of various grades for Research and Development work on Computers required by a large N. Kent Engineering firm. Qualifications: B.Sc., Higher National Certificate. Intermediate B.Sc. or equivalent. Salaries according to qualifications and experience. Write giving full particulars to Box No. W 2939.

A VACANCY exists in the Electronics Section of the Research Department for a Senior Electronic Engineer, with experience in the design of equipment for the electronic measurement of physical variables and associated problems in that field. The post is in an expanding organisation and offers opportunity for advancement. Applications, stating age, full details of qualifications, experience and salary required, should be addressed to the Personnel Officer, Saunders-Roe Limited, East Cowes, Isle of Wight. W 1335

A VACANCY EXISTS for a Senior Wireless Engineer to control a team engaged on research, development and engineering of new low power equipments in the 400-600 megacycle band. Salaries up to £1,200 per annum offered to suitable candidates. Please write giving full details and quoting Ref. HHE to Box No. W 2030.

A VERSATILE GLASSBLOWER required; part time, for work on small scale production of vacuum tubes. Slough, Bucks. Superannuation Scheme, canteen facilities, good salary paid to right applicant. Box No. W 1331.

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

DEVELOPMENT ENGINEER. A large engineering establishment in the N. Kent area requires the service of a Development Engineer with technical and practical experience in electronics. Preferred minimum qualifications the Higher National Certificate in Electrical Engineering. A knowledge of Servo Mechanisms would be an advantage. Reply, stating age and giving full particulars of experience and salary required to Box No. W 2938.

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

DIRECTOR of Engineering required to take charge of a highly technical Research and Development Company in the Greater London area (a subsidiary of a large Engineering Public Company). Applicants must possess a First Class Honours Degree and must have specialized in Electronics. Considerable experience is essential in the direction and management of research establishments, and the ability to guide and supervise teams of project engineers, design offices and model shops. Position carries a high salary, the possibility of an exceptional house and excellent long term prospects with pension facilities. All replies will be treated in full confidence. Write giving full details of qualifications, past experience and salary required to the Managing Director. Box No. W 1324.

DRAUGHTSMEN. Immediate vacancies exist for Senior and Junior Draughtsmen with light mechanical, electrical, or radio engineering experience to work on new project in a rapidly expanding industry. Applicants should have sound knowledge of materials and engineering methods. Production design experience would be an additional qualification. Good salaries offered to capable men seeking a progressive position in Bedfordshire. Applicants should write giving full details, quoting ref. ADD to Box No. W 2931.

E. K. COLE LTD., have vacancies in their Electronic Division at Malmesbury, Wilts., for senior and Intermediate Draughtsmen in the Development Drawing Office, for work on Radar, Communications and Electronic Projects. Previous experience in this field desirable but not essential. Apply in writing to the Personnel Manager, Ekco Works, Malmesbury, Wilts. W 2934

E. K. COLE (Electronics Division) offers excellent opportunities for young Draughtsmen of Ordinary National Standard to gain experience in the Development of Radar, Communications and Nucleonic Equipments. Also a limited number of vacancies for Senior Draughtsmen with experience of this type of work. Apply giving details of experience to Personnel Manager, E. K. Cole Limited, Malmesbury, Wilts. W 2971

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

ELECTRONIC and Radio Instruments. Chief Engineer required for development and production by small manufacturers in Home Counties. Salary £1,000-£1,500 according to qualifications. Write Box No. W 2996.

ELECTRONIC or Radio Engineer required to supervise a laboratory testing radio components including electrolytic and ceramic condensers, volume controls, and magnetic materials, etc. Applicants should be familiar with the properties of these components. Previous experience of testing desirable. State age, qualifications, salary required, etc. Box No. W 2036.

ELECTRONIC DEVELOPMENT ENGINEER required for work on a wide range of electronic instruments. Degree in Physics or Electrical Engineering essential and some industrial experience desirable. Apply Southern Instruments Ltd., Fernhill, Hawley, Camberley, Surrey. W 1334

ELECTRONIC/ELECTRICAL ENGINEER required with degree in Physics or Telecommunication Engineering, and at least four years experience of Radar. Apply Employment Manager, Vickers-Armstrongs Ltd., (Aircraft Section), Weybridge. W 2942

ELECTRONIC/ELECTRICAL ENGINEERS required with Higher National Cert. (electrical) and at least four years experience of Radar. Apply Employment Manager, Vickers-Armstrongs Ltd., (Aircraft Section), Weybridge. W 2943

CLASSIFIED ANNOUNCEMENTS
continued on Page 6

OFFICIAL APPOINTMENTS (Cont'd.)

would be of advantage for some posts. The range of salaries covered by these posts is approximately £250-£1,000 and grade and starting salaries will depend upon the age, qualifications and experience of the successful candidates. Some posts carry benefits of F.S.S.U. Application forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), York House, Kingsway, London, W.C.2, quoting A 200/51A. Closing date 24th August 1951. W 2022

PROFESSIONAL ENGINEERS in Government Departments. The Civil Service Commissioners announce an Open Competition to be held during 1951 for permanent appointments in many Departments of the Civil Service for a wide variety of engineering duties. Applications will be accepted at any time but not later than 31st December 1951, and selected candidates will be interviewed as soon as possible after the receipt of their Application Forms. Candidates are advised to apply as early as possible. Age Limits: Candidates must be under 35 on 30th November 1951 with extension for regular service in H.M. Forces and for established Civil Service. For appointments in the Post Office they must be 21 or over, in the Ministry of Supply, 23, and in all other Departments 25 or over on that date. Minimum qualifications vary for different posts. Generally a University Degree in Engineering or Corporate Membership of the Institutions of Mechanical Engineers, Electrical Engineers or Civil Engineers, or passes in or exemption from Sections A and B of the corresponding Associate Membership examinations, or evidence of exceptionally high professional attainment are required. For certain posts, Corporate Membership of the Institute of Fuel by examination or the Institution of Chemical Engineers, or Graduate Membership of the Institution of Chemical Engineers or Associate Fellowship of the Royal Aeronautical Society or an Honours Degree in Physics will be accepted instead. The salary on appointment will be fixed according to age. The salary for men aged 26 in London is £500 rising by annual increments of £25 to £750. Salaries for women and for posts outside London are lower. There are prospects of promotion to higher grades on scales for men in London of £750-£1,000, £1,050-£1,270 and above. These rates are at present under review. Further particulars and application forms from Secretary, Civil Service Commission, Trinidad House, Old Burlington Street, London. W.1, quoting No. S85/51. W 2003

PROFESSIONAL ENGINEERS in Government Departments. The Civil Service Commissioners announce an Open Competition for permanent appointments of Professional Engineers, General Service Class (Main and Senior grades). The vacancies at present announced are in the Admiralty (about 8 in the Main Grade and at least one in the Senior Grade), but vacancies in other Departments may be announced later. The duties in the Admiralty cover the production of mechanical, electrical and electronic equipment for H.M. Ships and include design for production, correlation of manufacturing requirements and capacity, advice on production methods, preparation of estimates and, in certain cases, material inspection and functional testing. Candidates must be at least 30 years of age on 1st January 1951. Minimum Qualifications: Generally Corporate Membership of the Institutions of Mechanical Engineers, or Electrical Engineers is required, together with evidence of apprenticeship or pupilage and subsequent engineering experience. Exceptionally, candidates of high professional attainments without some or all of these qualifications may be admitted. Salary scales:- Main Grade. Men —£750-£1,000. Women—£650-£850 (London). Men—£720-£960. Women—£620-£810 (Provinces). Senior Grade. Men—£1,050-£1,270. Women—£900-£1,100 (London). Men—£997-£1,192. Women—£860-£1,040 (Provinces). These rates are at present under review. Further particulars and application forms from Secretary, Civil Service Commission, Trinidad House, Old Burlington Street, London, W.1, quoting No. S86/51. Applications will be accepted at any time but not later than 31st August, 1951, and selected candidates will be interviewed as soon as possible after receipt of their Application Forms. Candidates are advised to apply as early as possible. W 2032

ROYAL NAVAL SCIENTIFIC SERVICE. Principal Scientific Officers and Senior Scientific Officer. The Civil Service Commissioners invite applications for the following permanent appointments. (1) Four Principal Scientific Officers at an Admiralty Establishment in the South of England—(a) One Mechanical Engineer with considerable design experience and a flair for design. The successful candidate will be required to study and to solve the special problems connected with the design of modern radar aerials and their associated scanning and rotating mechanisms. (b) One Engineer who has had wide experience in, and complete responsibility for, the successful engineering of complex projects involving many different specialist component parts both electrical and mechanical. The candidate chosen will be responsible for such projects to the final development of completed prototype models. (c) One Electronics Engineer with outstanding ability in precision designs associated with complex electronic equipment. A knowledge of modern circuitry will be a distinct advantage. (d) One Engineer with high grade experience of the theory, design and utilisation of Servo-mechanisms. (2) Two Principal Scientific Officers at an Admiralty Establishment in the Home Counties. Candidates must be Mechanical Engineers with considerable experience in the design of intricate mechanisms; must have an intense interest in such work and possess originality, inventiveness and a general appreciation of the physical and metallurgical problems involved. (3) One Senior Scientific Officer or Principal Scientific Officer (according to age and experience) at an Admiralty Establishment in the Home Counties. Candidates must be Physicists or Electronic Engineers with an excellent theoretical understanding and practical experience of and responsibility for the design and development of electronic circuits, especially in the high and medium frequency bands. A knowledge of modern receiver techniques is also required. Candidates for the above posts should normally possess either a First or Second Class Honours Degree in Engineering or Physics as appropriate or be corporate members of one of the Professional Institutions or be able to produce evidence of other high professional or academic attainments or qualifications which will enable them to carry out the duties required. (4) One Principal Scientific Officer at an Admiralty Establishment at Rosyth. The successful candidate will be required to supervise the work of Applied Mathematicians and Engineers in the Structural Mechanics Division. Experience in the stressing of plate and beam structures with knowledge of modern work in the fields of buckling and deformation of stiffened plate structures or shells is essential. Candidates must be Structural Engineers with a First or Second Class Honours Degree in Engineering, or Mathematicians with an Honours Degree in Mathematics, and with experience in Applied Mathematics in these fields of Structural Mechanics. (5) Candidates must have been born on or before 1st August, 1920. The Senior Scientific post (and similarly graded Scientific posts in other Government Departments) is also open to candidates born between 2nd August, 1920 and 1st August, 1925 (inclusive) through the Open Competition under Normal Regulations already announced (No. 3399). Inclusive London salary scales:- Principal Scientific Officer—Men: £1,000-£1,375. Women: £880-£1,200. Senior Scientific Officer—Men: £700-£900. Women: £575-£800. The Senior Scientific Officer scale of pay is under review. Rates for posts outside London are somewhat lower. Exceptionally a starting salary above the minimum may be granted according to qualifications and experience. Posts carry benefits under Federated Superannuation System for Universities. Forms of application and further particulars from Secretary, Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S.4043/51. Completed application forms must be returned by 9th August, 1951. W 2004

ROYAL NAVAL SCIENTIFIC SERVICE: Senior Experimental Officer or Experimental Officer. The Civil Service Commissioners invite applications for five permanent appointments as Senior Experimental Officer or Experimental Officer for duty at home or overseas. Candidates for the Senior Experimental Officer grade must have been born on or before 1st August, 1916 and for the Experimental Officer grade on or before 1st August, 1923. Candidates must have proved their ability as telecommunications engineers. They must have had experience of modern radio equipment and be capable of supervising the maintenance, repair, installation, modification and operation of all forms of such equipment including modern high speed recording apparatus. Knowledge of modern directional aerial techniques is essential. Normally every candidate must also possess one of the following qualifications or one accepted as equivalent:- (a) A Higher National Certificate or Higher National Diploma in Electrical Engineering. (b) The City and Guilds of London Institute's final Certificate in Telecommunications Engineering. (c) Graduate membership of the Institution of Electrical Engineers. (d) A University Degree in physics or engineering. But candidates who do not possess such a qualification may be admitted exceptionally if evidence of suitable experience in research or development work in the field of telecommunications engineering can be produced. Inclusive London salary scales are:- Senior Experimental Officer—Men: £780 x 30—£1,000. Women: £655 x 30—£900. Experimental Officer—Men: £575 x 25—£725. Women: £485 x 25—£600. Rather less in the provinces. Starting salary will be determined on an assessment of the successful candidates' qualifications and experience. There are opportunities for members of the Experimental Officer Class to enter the Scientific Officer Class, the highest scientific class in the service. Further particulars and application forms from Secretary, Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S.4048/51. Completed application forms must be returned by 16th August, 1951. W 2019

TELECOMMUNICATIONS Engineers and Physicists are invited by the Ministry of Supply to apply for unestablished appointments in the grade of Principal Scientific Officer or Senior Scientific Officer at the Royal Aircraft Establishment, Farnborough, Hants. Candidates should have a 1st or 2nd class Honours Degree in physics or telecommunications and upwards of 5 years experience of research and development in one of the following:- R.F. techniques at centrimetric wavelengths; centrimetric radar, preferably for airborne application; servo systems or telecommunication networks and feedback amplifiers. For the P.S.O. grade candidates must be at least 31 years of age and for the S.S.O. grade at least 26. Salary will be determined on age and on an assessment of the successful candidates' qualifications and experience within the ranges:- Principal Scientific Officer £960-£1,295. Senior Scientific Officer £720-£910. Rates for women somewhat lower. Posts carry benefits of F.S.S.U. Application forms obtainable from Technical and Scientific Register (K), York House, Kingsway, W.C.2, quoting D 158/51 A. W 2037

THE COLLEGE OF AERONAUTICS. Lecturer in Electrical Engineering. Applications are invited for the post of Lecturer in Electrical Engineering in the expanding Electrical Section of The College of Aeronautics. The Lecturer will be required to take charge of the fundamental theoretical and practical work on aircraft electrical systems (excluding radio and radar). Subjects to be covered are those connected with the design of electrical machines for use in aircraft, and installation problems and practices connected therewith. Applicants should have a Degree in electrical engineering and preferably should have had industrial experience. Some knowledge of allied subjects such as servo-mechanisms theory and practice, thermionic techniques, etc., is desirable and teaching experience would be an advantage. Salary will depend on qualifications and experience. The salary range for lecturers at the moment is £500 to £750 per annum with family allowance and superannuation under the F.S.S.U. If the successful candidate is married, it may be possible to offer tenancy of a small house. Applications giving full details of qualifications and experience and quoting the names of three referees should be addressed to the Registrar, The College of Aeronautics, Cranfield, Bletchley, Bucks., and the envelope endorsed "Lecturer in Electrical Engineering." Further information may be obtained from the Registrar if required. Closing date for the receipt of applications is 15th August, 1951. W 2018

THE MINISTRY OF SUPPLY requires skilled Research and Experimental Mechanics in various trades including Turners, Sheet Metal Workers, Millers, Capstan Setter Operators, Fitters, Toolmakers, Joiners, Electro Platers, Woodcutting Machinists, and Electronic Mechanics for service at M.C.S. Establishments in Kent and South East London. Details of wages and conditions of service will be given on application. Apply, giving particulars of apprenticeship, training, qualifications and experience, and whether Kent or South East London preferred, to the Chief Registrar, Ivybridge House, Adam Street, London, W.C.2, quoting L5/835/51. W 2028

CLASSIFIED ANNOUNCEMENTS
continued on Page 4

CLASSIFIED ANNOUNCEMENTS

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

OFFICIAL APPOINTMENTS

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

ADMIRALTY. Vacancies exist in the Electrical Engineering Department, Admiralty, Bath, for:- (i) Temporary Technical Class Grade III officers experienced in production methods and/or estimating and costing. (ii) Temporary Draughtsmen. Candidates for both grades must be British subjects of 21 years of age and upwards and have served an apprenticeship or had equivalent workshop experience followed by experience in one or more branches of electrical engineering manufacture. In addition Drawing Office experience will be required for immediate appointments as Temporary Draughtsmen, but selected Technical Class Grade III candidates who fulfil the foregoing conditions and who, but for the lack of sufficient Drawing Office training would be acceptable in the Temporary Draughtsmen vacancies, will be given a course of training in drawing and allied subjects at the Bath Technical College with a view to being regraded as Draughtsmen. Fees for the course will be paid by the Admiralty and trainees will be paid their normal salaries during the training period. Salaries applicable to both of above mentioned grades range up to a maximum of £545 per annum and will be assessed according to age, qualifications and experience. Applications stating age, details of technical qualifications and apprenticeship (or equivalent) and workshop experience should be sent to the Admiralty, Empire Hotel (C.E.II, Room 88, Section E.E.D.) Bath. Candidates selected for interview will be advised within two weeks of receipt of application. W 2029

ADMIRALTY: Principal Scientific Officer and Senior Scientific Officer. The Civil Service Commissioners invite applications for permanent appointments in the Royal Naval Scientific Service. Principal Scientific Officer. Post (a) a physicist or electrical engineer possessing a high class Honours Degree, with research experience in telecommunications with special emphasis on all radio telephony methods and High Speed telegraphy; the duties to be undertaken call for a profound analytical outlook as the successful candidate will be concerned with investigations rather than the development of equipment. Two Senior Scientific Officers. Post (b) a physicist possessing a high class Honours Degree with research experience and a considerable knowledge of electronic circuitry; the successful candidate would work with a Principal Scientific Officer in the research and development of High Speed electronic computing equipment; a knowledge of display circuits, high speed recording and storage will be an advantage. Post (c) a physicist or electrical engineer possessing a high class Honours Degree, with experience in telecommunication research with emphasis on radio telephony and High Speed telegraphy problems; the successful candidate would work with the principal Scientific Officer mentioned at (a) above and must be of a calibre to design the associated equipment. Candidates must have been born on or before 1st August 1920. The posts b and c (and similarly graded Scientific posts in other Government Departments) are also open to candidates born between 2nd August 1920 and 1st August 1925 (inclusive) through the Open Competition under Normal Regulations already announced (No. 3399). The appointments in the first instance will be to Establishments in the Greater London area but transfer to the provinces will probably be involved later. Inclusive London salary scales:- Post (a) men, £1,000-£1,375; women, £880-£1,200. Posts (b) and (c) men, £750-£950; women, £625-£850. Rates for posts outside London are somewhat lower. Exceptionally a starting salary above the minimum may be granted according to qualifications and experience. Post carry benefits under Federated Superannuation System for Universities. Forms of application and further particulars from Secretary, Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S 4049/51. Completed application forms must be returned by 23rd August 1951. W 2033

ADMIRALTY. Vacancies exist for Electrical and/or Mechanical Engineering Draughtsmen in Admiralty Research and Development Establishments located in the vicinity of Weymouth, Portsmouth, Teddington (Middlesex), and Baldock, Herts. Draughtsmen experienced in light current, electro-mechanical, precision mechanical and electronic equipment are particularly needed. Candidates must be British subjects of 21 years of age and upwards, who have had practical workshop experience (preferably an apprenticeship) together with Drawing Office experience. Appointments will be in an unestablished capacity but opportunities may occur for qualified staff to compete for established posts. The salaries offered, depending on age, experience, ability and place of duty, will be within the range £320—£560 p.a. Hostel accommodation is available at some Establishments. Applications stating age and details of technical qualifications, apprenticeship (or equivalents), Workshop and Drawing Office experience, should be sent to Admiralty (C.E.II, Room 88) Empire Hotel, Bath, quoting DM/R.D. Original testimonials should not be forwarded with application. Candidates required for interview (at London or Bath, whichever is nearer) will be advised within two weeks of receipt of application. W 2984

APPLICATIONS are invited by the Ministry of Supply for the following unestablished appointments at the Royal Aircraft Establishment Farnborough, Hants.:- Physicists or Mathematical Physicists. (1) Principal Scientific Officer. Candidates should have experience of Radar systems analysis and war-time operational research. A strong mathematical bias is desirable. Ref. A 133/51A/BE. (2) Senior Scientific Officer, for theoretical investigations. A knowledge of statistical methods is desirable. Ref. A 134/51A/BE. Aeronautical Engineer. (3) Senior Scientific Officer with experience in planning and analysis of Flight trials and application of results to project design. A knowledge of servo mechanisms theory and practice is required, experience of liaison with industrial firms an advantage. Ref. C 217/51A/BE. Physicists, Mathematicians or Engineers. (4) Senior Scientific Officer, with research experience involving arithmetical applications of mathematics in the analysis of physical data, and the formulation of problems for solution by automatic computing machinery. A knowledge of aerodynamics an advantage. Ref. A 135/51A/BE. (5) Senior Scientific Officer with wide experience of methods of measurement in physics or engineering research, experience and up-to-date knowledge of electronics. Ref. A 136/51A/BE. Candidates should have a first or second class Honours Degree in the appropriate subject and at least 3 years post-graduate research experience is necessary. For the P.S.O. post candidates must be at least 31 years of age, for the S.S.O. post at least 26 years. Salary will be determined on age and on assessment of the successful candidates' qualifications and experience within the ranges:- Principal Scientific Officer —£960-£1,295. Senior Scientific Officer—£720-£910. Rates for women somewhat lower. Posts carry benefits of F.S.S.U. Application forms obtained from Technical and Scientific Register (K), York House, Kingsway, W.C.2, quoting appropriate reference number. W 2026

COMMONWEALTH Technical Co-operative Scheme. Applications are invited by the Commonwealth Relations Office for the post of Expert Radar Technician for a Radar wind finding station in Colombo under the Government of Ceylon, at a salary of £1,000 to £1,200 per annum. An allowance will be paid to cover board and lodgings, and free medical attention will be available. Return passage of the person appointed will be paid together with cost of local travel on duty. Arrangements for leave and the passage of dependents by negotiation. Applicants preferably between the ages of 35 and 45, should have a Higher National Certificate or be of R.T.G.B. and City and Guilds standard. They must have considerable Servicing and maintenance experience of Radio and Radar and preferably a knowledge of G.L.III sets. The selected applicant will be responsible to the Director, Department of Meteorology and will be expected to take over and maintain the station equipment and train local staff on routine maintenance. The duration of appointment is approximately three years. Forms of application may be obtained from the Ministry of Labour and National Service, Technical and Scientific Register (K), York House, Kingsway, W.C.2, quoting D 324/51/0/A. W 2027

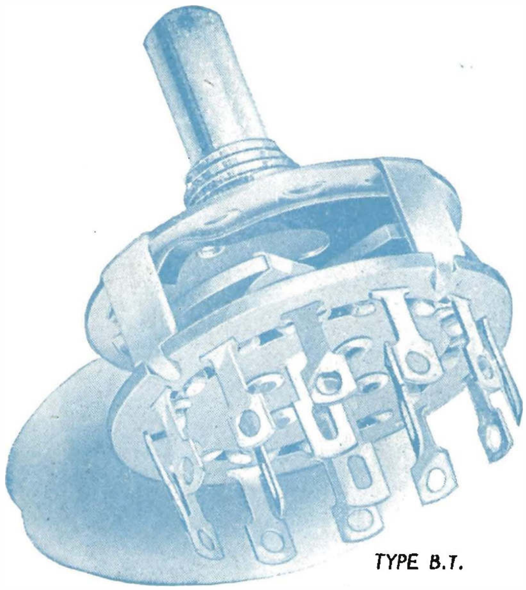
ELECTRICAL ENGINEERS and Physicists are invited by the Ministry of Supply to apply for unestablished appointments in the grade of Senior Scientific Officer at the Royal Aircraft Establishment, Farnborough, Hants. Candidates should be at least 26 years of age and have a 1st or 2nd class Honours Degree in the appropriate subject and at least 3 years post-graduate research experience. They should also have a wide knowledge of communications work and H.F., V.H.F. or display techniques for research work associated with design and development of airborne and ground equipments. Salary will be determined on age and on an assessment of the successful candidate's qualifications and experience within the S.S.O. range £720-£910. Rates for women somewhat lower. Posts carry benefits of F.S.S.U. Application forms obtainable from Technical and Scientific Register (K), York House, Kingsway, W.C.2, quoting D 159/51 A. W 2038

ELECTRONIC ENGINEERS are invited to apply for appointments in the Ministry of Supply to work near London or at provincial stations on the development and design of electrically operated systems for a variety of applications including weapons, telecommunications and radar equipment. The responsibilities of the posts will vary according to the age, qualifications and experience of the selected candidates and acceptable qualifications range from 1st or 2nd Class Honours Degree in physics or light electrical engineering or equivalent qualifications, Corporate Membership of the Institution of Electrical Engineers to Higher School Certificate, Higher National Certificate, etc. Grade and entering salary will be determined after interview on ranges up to approximately £1,000 a year. Some posts carry F.S.S.U. benefits, but all are unestablished. Application forms obtainable from M.L.N.S., Technical and Scientific Register (K). York House, Kingsway, W.C.2, quoting D.134/51A. Closing date 24th August 1951. W 2011

PERSONNEL EXPERIENCED in the maintenance and repair of Electronic Control Equipment and Radar Equipment as applied to Anti-Aircraft Guns, are required for Employment as civilians in the following areas:- Guildford, Portsmouth, Southampton, Bristol, Gloucester, Andover, Central Dorset and Bournemouth. The standard required is that of Armament Artificer, R.E.M.E. Salary £380 x £20 to £495, linked to the age of 26. One increment deducted for each year below 26 years and up to two increments added over 26 years. Opportunities exist for promotion to higher grades. Replies giving full details of age, experience, technical qualifications, and service ranks held (if any), should be sent to :- A.D.M.E. H.Q., 2 A.A. Group, Barrosa Barracks, Stanhope Lines, Aldershot, Hants. W 2021

PHYSICISTS are invited by the Ministry of Supply to apply for unestablished appointments at a Research Establishment near London for work connected with the handling and measurement of radioactive materials and associated health physics problems. Certain posts call for a 1st or 2nd class honours Degree preferably followed by some research experience, other posts are open to candidates with Inter Science qualifications although higher qualifications would be an advantage. A knowledge of electronics, including the ability to design and construct counters and other electronic equipment

Which switch fits the niche?



TYPE B.T.

By the time that has rolled round your tongue half a dozen times the Type B.T. Switch could be fitted! It's that sort of switch—small, compact, designed specially to fit easily into small spaces. It'll save you a lot of trouble. We have recently included some new features. Here they are—

- **The contact blades are fixed in a new way. This makes them completely rigid all the time.**
- **The drive spindle is positioned definitely in the wafer. This provides double bearing.**
- **Steady contact resistance.**
- **Improved insulation between contacts.**
- **Positive contact.**
- **Self-cleaning action.**

All these make the Type B.T. a better switch—more efficient and lasting. In fact just the switch you need for limited space and simple switching.

WALTER SWITCHES—MADE FOR LIFE

Walter Instruments LIMITED

WALTER INSTRUMENTS LIMITED, GARTH ROAD, LOWER MORDEN, SURREY. TELEPHONE: DERWENT 4421-2-3

C.R.C.47

10kV with a rectifier only 8.75" long

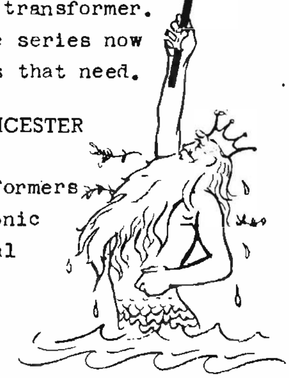
STANDARD engineers have achieved considerable progress in miniaturisation with their high voltage SenTerCel Tubular Selenium rectifiers. Take for example Type K3/140 ; only 8¾" long and ⅜" in diameter it will provide a rectified output up to 10kV at 100 microamps across a capacitor of 0.005 microfarads in a pulse input half-wave arrangement.

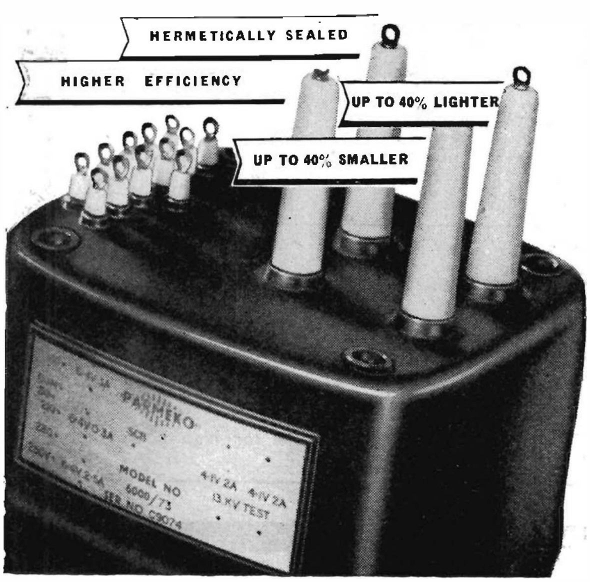
Two ranges of tubular rectifiers are available having rated current outputs of 1mA and 5mA in ambient temperatures up to 55°C. Each range includes stacks capable of withstanding a peak inverse voltage of 68V to 13.6kV per stack with a sinusoidal input.
Due to their low cost, they are ideal for use in television receivers and are eminently suitable for all other types of low current E.H.T. supplies.

Please ask for leaflet F/SRL 11

SELENIUM
SenTerCel
RECTIFIERS
REGISTERED TRADE MARK

Standard Telephones and Cables Limited RECTIFIER DIVISION
Registered Office: Connaught House, Aldwych, London, W.C.2
Warwick Road, Boreham Wood, Herts. *Telephone: Elstree 2401. Telegrams: SenTerCel, Borehamwood*





Electronic Engineering

Incorporating
ELECTRONICS, TELEVISION and SHORT WAVE WORLD

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

Vol. XXIII　　**AUGUST 1951**　　No. 282

In This Issue

Commentary ...	285
An Electronic Digital Computor ... By R. C. M. Barnes, B.Sc., E. H. Cooke-Yarborough, M.A., A.M.I.E.E., and D. G. A. Thomas, M.A.	286
The Design and Operation of Television Cathode Ray Tubes ... By L. S. Allard, B.Sc., A.Inst.P.	292
A Three Dimensional B.H. Loop Display ...	297
X-rays Applied to the Manufacture of Low Temperature Co-efficient Quartz Crystals ... By J. R. Halsall	298
P.E.C. Control in Laundries ...	301
Winding Space Determination ... By N. H. Crowhurst, A.M.I.E.E.	302
College of Aeronautics Presentation and Open Day	306
Application of Matrices to Four Terminal Network Problems ... By H. P. Biggar	307
A Rapid Means of Calculating the Shunt Loss of an Output Transformer ... By M. P. Johnson, A.M.I.E.E.	310
A Simple Phase Shifting Device ... By G. N. Patchett, Ph.D., B.Sc., A.M.I.E.E., M.I.R.E.	310
A Process Timer ... By G. S. Errington	311
The University of Manchester Digital Computor ...	312
A Simple Method of Indicating Makes and Breaks By K. J. Brimley, B.Sc.	313
The Telekinema at the Festival of Britain ... By V. E. Hughes	314
Sound Distribution and Crowd Control at the South Bank ...	316
Notes from the Industry ...	317
British Instrument Industries Exhibition ...	318
Electronic Equipment ...	320
Book Reviews ...	322

Published Monthly
on the last Friday of the preceding month at 28 Essex Street, Strand, London, W.C.2.
Telephone CENTRAL 6565
Telegrams 'LECTRONING, ESTRAND, LONDON'

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

Classified Advertisements, Page 1.
Index to ADVERTISERS, Page 44

Electronic Engineering

Vol. XXIII. **AUGUST 1951** No. 282.

Commentary

AS we are going to Press this month, the Government's views on the Beveridge Report have been made known, and they are published in the form of a White Paper (Cmd 8291).

It will be recalled that the Broadcasting Committee was set up in 1949 under the chairmanship of Lord Beveridge to advise on sound and television broadcasting services in the United Kingdom and that the Committee's Report, issued at the beginning of this year, would be fully debated in Parliament as soon as a convenient time could be arranged.

Comment therefore on the final decisions to be taken on the Report must therefore wait until both Houses have expressed their views, which they will have done by the time this issue appears in print. But it appears from the White Paper that the Government's views are, in fact, an endorsement of the Beveridge Report and therefore no surprise need be occasioned by the recommendation to continue the British Broadcasting Corporation on its present basis. In short, the new Charter to be granted in January next will be an extension for another fifteen years of the present monopoly; sponsored programmes and advertising are out, and debate therefore is likely to be centred on what are relatively minor matters of detail.

We have remained unconvinced by the arguments in favour of alternative schemes to the present monopoly of the B.B.C. in spite of its many weaknesses, and we are therefore all the more alarmed by the Government's rejection of the recommendation that the B.B.C. should be allowed to retain the whole of present licence fees for the first five years of the new Charter. In the view of the Government, only 85 per cent should go to the Corporation, the balance going to general revenue purposes, although authorization would be given for the B.B.C. to borrow up to £10 million for capital expenditure.

One of the arguments in favour of the continuance of the monopoly is that any alternative would ultimately result in a serious decline in the service to the public in programme standards and technical development, yet this suggestion, coming on top of another recently made in the House that the B.B.C. should be called upon to make a contribution towards the cost of rearmament, would do precisely this if carried out.

We hope therefore that this proposal will be most strongly resisted, for already the scheme for the installation of the five low-power television transmitters has been abandoned early this year on account of the rearmament programme and is unlikely to be taken up again for some considerable time.

With the curtailment of this scheme and the recent increase in Purchase Tax on television receivers, the B.B.C.'s income is not likely to do more than remain steady over the next few years and if the television service is not to diminish, the only alternative to sponsored programmes is an increase in the licence fee.

Unfortunately the burden of taxation is so heavy and new sources of revenue so difficult to raise that it is very tempting for the Government to raid the funds of what is, in effect, an organization supported entirely by the voluntary subscriptions from the general public. Once started, it is all too easy to continue and we would quote the Road Fund as an example.

* * *

Earlier last month, the British instrument industry held an exhibition at the National Hall, Olympia, which was the first of its kind. Devoted entirely to instruments in current production and representing the products of some hundred and fifty firms, it was sponsored by five trade organizations including the Scientific Instrument Manufacturers' Association.

It is perhaps not generally known that the British instrument industry, employing no less than 50,000 people, most of whom are highly skilled craftsmen, is making a valuable contribution to the economy of the country by exporting annually some £14 million of its products.

Many of the instruments on view have, of course, been seen earlier this year at the Physical Society's Exhibition, but nevertheless the Exhibition has been of value. We hope, therefore, that if it is to become an annual event it will be fully supported by the industry and its scope extended so that it will be the exhibition of the year at which new instruments will receive their first showing. We have long held the view that the Physical Society's Exhibition is suffering from growing pains and that the trade or commercial side has tended to overwhelm the pure research and development items. The removal of the trade section to an annual instrument exhibition would, in our view, do much to relieve the congestion at Imperial College without in any way detracting from the importance of the Physical Society's Exhibition there.

An Electronic Digital Computor

Using Cold Cathode Counting Tubes for Storage

(Part 1)

By R. C. M. Barnes, B.Sc., E. H. Cooke-Yarborough, M.A., A.M.I.E.E., and D. G. A. Thomas, M.A. *

A small sequence-controlled computor is described; it has storage capacity for up to 90 numbers each of eight decimal digits. Cold cathode counting tubes (Dekatrons) are used as storage elements. Parallel operation is employed, and the speed of operation is comparable with that of a desk calculating machine. Apart from speed, however, the computor provides most of the facilities found in larger, faster digital computors. Information is fed into the machine from perforated paper tapes and a teleprinter or tape perforator records the results.

SEVERAL large-scale computors have been described in recent years, including the ENIAC[1,2] with hard valve circuits, the EDSAC[3,4] with mercury delay storage, the University of Manchester computor[5,6] with cathode-ray storage and the Birkbeck College computor with magnetic storage.[7,8] These computors are intended primarily to carry out enormous computations, too lengthy to perform by other means. In addition smaller scale relay computors[9,10] have been built for general work. The machine described here is not intended to deal with the long calculations for which the large computors have been designed. It is intended rather to do the work of a few operators with desk calculating machines where the work to be done is of a routine or repetitive nature. As a result, simplicity and reliability have been regarded as of more importance than speed of operation and the machine performs the operations of addition, subtraction, multiplication and division little faster than a desk calculator.

Fig. 1 is a schematic diagram of this machine. The design can, for convenience, be regarded as consisting of two parts. The first includes the means by which the machine receives orders, controls the sequence of operations and the routing of numbers to and from the stores, and prints the results. The second part consists of the means of storing numbers and, closely allied with this, the arithmetic unit in which the arithmetical processes take place. In the present machine these two parts are almost entirely separate.

Because a relatively low operating speed is accepted, it becomes practical to read orders and other data from the perforated tape as they are needed in the calculations (this is done in the B.T.L. machine[9,10]). Design is thus simplified and much less storage capacity is needed. The low operating speed also makes possible the use of relays for routing and sequence control. Since each relay may carry many contacts this leads to simplicity in setting up connexions. The fact that the techniques are well established and of proved reliability is of great importance.

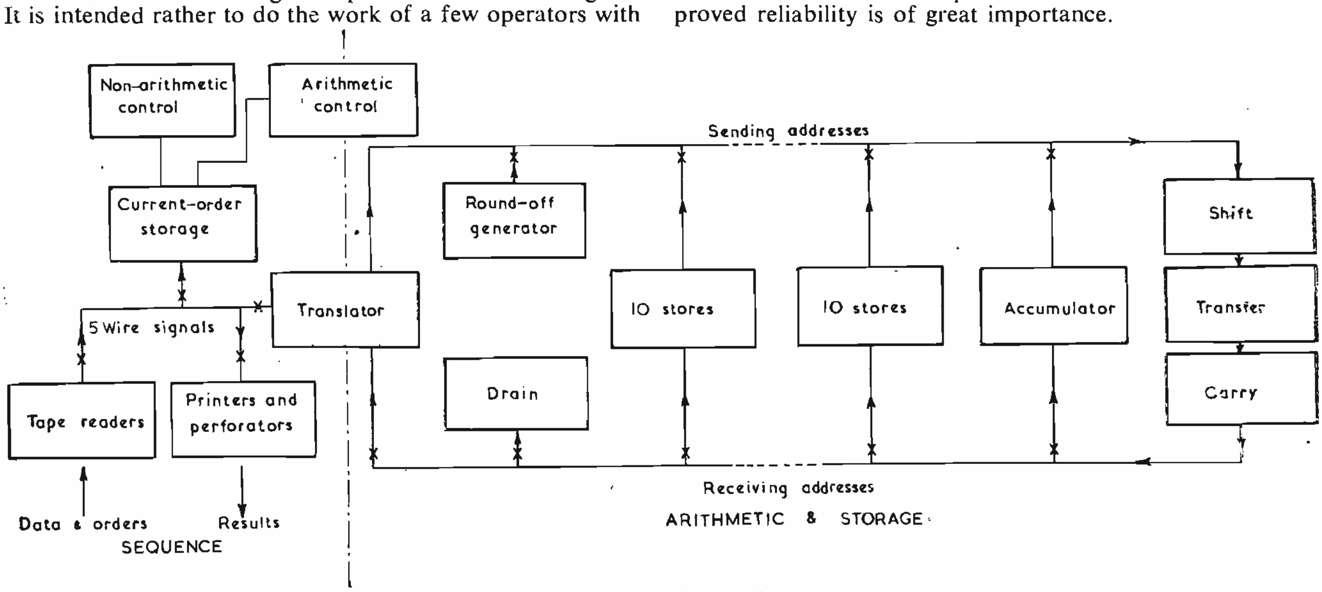


Fig. 1. Block schematic diagram of computor.

Numerical data obtained in the course of the calculation must be stored in the machine. The use of relays for number storage is not attractive, as many relays would be needed. Other methods were considered, largely for their suitability for use in a computor with relay routing, and it was eventually decided to make use of cold cathode counting tubes ("Dekatrons"). These were recently described[11] and are coming into increasing use for scaling and counting purposes. In these tubes, a gas discharge may be stepped round in to any of ten stable positions, and each tube is therefore capable of storing a decimal digit. The tubes have the advantage that numbers can be fed into them, or obtained from them, by use of relatively simple circuits. Moreover the numerical information is in the form of large amplitude pulses (tens of volts), so the possibility of spurious pulses being introduced from external

* *Electronics Division, A.E.R.E., Harwell.*

sources is much reduced by comparison with other storage methods. Use of these tubes permits the computor to work on a decimal, rather than a binary, basis. This is convenient from several points of view; it is particularly advantageous in a parallel computor, since the number of digits and therefore the number of parallel arithmetical units, is considerably reduced.

Provided that the number of stores required is not too large, this method of storage is thought to compare favourably with other methods on the basis of cost, size, and power consumption per digit. When the computor is fitted with its full storage capacity (90 eight-digit numbers, equivalent to 2,700 binary digits) just over 800 tubes will be used. The power consumption is about $150\mu A$ per tube at 370V. From the fact that the tubes operate at this low current and from life tests to date, tube life is expected to be many thousands of hours.

Each storage address consists of nine tubes, corresponding to eight digits with one additional tube to indicate the sign. The decimal point is regarded as being after the first figure of the number stored, whether this is a significant figure or zero, and the capacity n of each store is $+10 > n > -10$.

Numbers are fed into stores and handled in the arithmetic unit as trains of pulses. Negative numbers are handled as complements except on the punched tape and when finally printed, when they appear as modulus and sign. The basic process of addition (or subtraction by addition of the complements) is carried out electronically in order to save the wear that would occur if high speed relays were used. Multiplication and division is by a sequence of multiple additions (or subtractions), with the operation of a relay circuit to shift the decimal point as each multiple addition takes place.

No provision is made for reading off tables of functions and the low operating speeds will often make it impracticable to calculate the required functions *ab initio*. This must be regarded as a limitation of the present machine; it may eventually be overcome by providing a special table-reading attachment.

The computor has been operating with 20 eight-digit stores for some months. This has made possible the establishment of most of the electronic and relay circuits. Although the machine has not yet been put into service it seems appropriate at this time to publish details of the design which has been established.

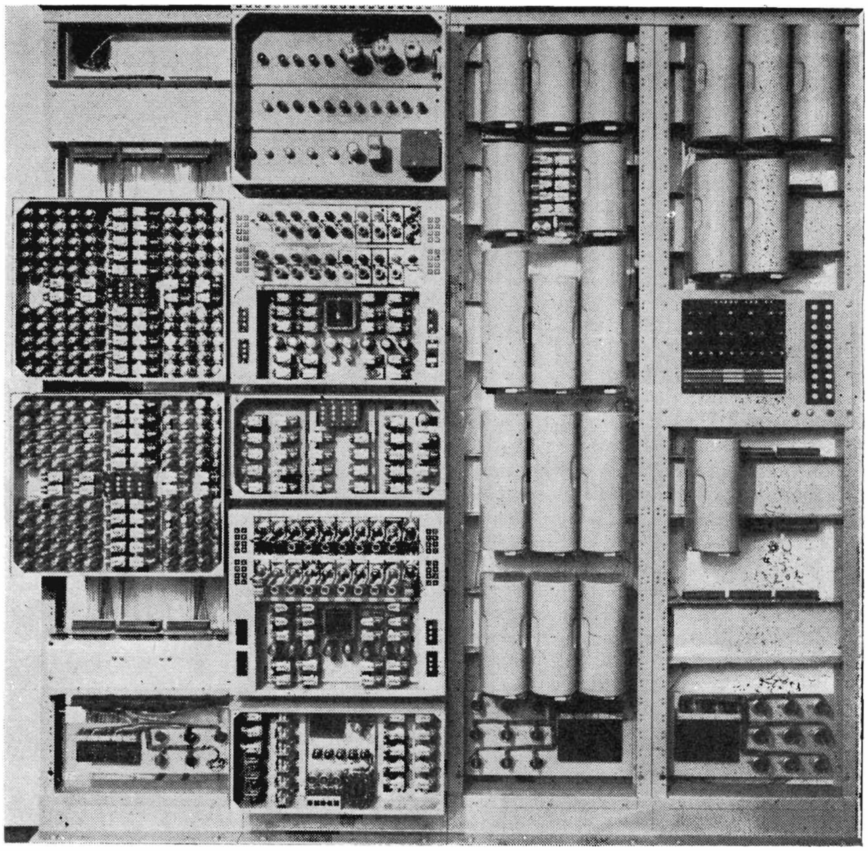
The computor contains about 380 relays, 18 Dekatrons, 80 thermionic valves and 40 cold cathode triodes, plus 28 relays and 90 Dekatrons per ten stores. It occupies three 7 ft. Post Office racks, together with an additional rack per four groups of ten stores, one smaller rack for the power supplies and a table for tape readers and printers. Total power consumption is about 1kW.

Facilities

The computor operates solely under the control of orders and data fed in from perforated paper tapes, and no manual switching or plugging up is necessary. Provision is made for a maximum of eight input tapes read by separate tape readers. Each tape may contain orders, input data, and constants. A typical allocation of tapes is expected to be a master programme tape, a tape giving the data relevant to the particular problem and a number of closed loops containing the longer sub-routines.

The output of the computor is fed into either a perforator or a modified teleprinter operating as a page printer. A maximum of eight printers and perforators can be accommodated although only a few of the positions are used at present. It is possible to feed the perforated tape from an output perforator into an input tape reader to give a long-term storage when the nature of the work permits.

The first order is always read from tape reader No. 01 and subsequent orders come from the same source until an order specifies a change. If the source of orders is changed to a Dekatron number store, orders are drawn from successive stores until the sequence is interrupted. Orders are normally only stored in the Dekatron stores when they take the form of short sub-routines or if they are to be subjected to arithmetical operations; the majority of orders will be read directly from the tape readers.



Computor fitted with 20 stores, but excluding tape readers, printers and power supply. The left hand rack carries two units each of ten stores. The left centre rack carries the electronic pulse generator (top), the arithmetic units with relay shift unit (centre) and the translator unit (bottom). The two right hand racks contain the relay sequence control circuits.

Orders appear on the tape as blocks of five (decimal) digits and each digit is represented by one row of perforations. Numerical data are perforated as blocks of eight digits preceded by a sign character. Blocks of digits are separated by a character which can be either a space or one of ten block-marking characters. A search facility is provided by which any tape reader can be made to search along its tape until it finds the required block-marking character.

Arithmetical Orders

Arithmetical orders consist of one digit defining the arithmetical operation to be performed, a sending address (two digits) and a receiving address (two digits). The sending address may be a Dekatron store, the accumulator, a tape reader, or the rounding-off circuit. The receiving address may be a store, the accumulator, a printer or perforator, or a drain for unwanted numbers. Seven operation digits have been allocated as follows:

(1) Add the contents of the sending address into the receiving address, and leave the contents of the sending address unchanged.
(2) Add the contents of the sending address into the receiving address and clear the sending address.
(3) Subtract and do not clear the sending address.
(4) Subtract and clear the sending address.
(5) Multiply the contents of the sending address by the contents of the "receiving address" clearing the latter, and add the product into the accumulator.
(6) Divide the contents of the accumulator by the contents of the sending address, form the quotient in the receiving address and leave the remainder in the accumulator.
(7) Add the positive modulus of the contents of the sending address into the receiving address.

The sending and receiving addresses must not lie in the same group of ten stores; in the case of multiplication and division they must not refer to an input or output organ. It should be noticed that addition and subtraction do not require the use of an accumulator, because the result of a direct transfer of the contents of a store into an already occupied store is to form a sum. In this operation the original number in the latter store is lost unless it is also stored elsewhere. The accumulator is only required as a third address, of length 15 digits, for the purpose of multiplication and division, but it can be used exactly as a normal store at other times.

NON-ARITHMETICAL ORDERS

In non-arithmetical orders the operation digit is "0" and is followed by two further digits calling for a change of the address from which orders are obtained, search for a block-marking character, examination of the sign of the number in a specified address, or selection of the layout of the printed result. The last two digits specify the address concerned.

The sign examination facility allows the future action of the computor to be controlled by the state reached by the calculation. Any store can be examined for the presence of either a positive or a negative sign. If the sign looked for is found, an affirmative relay is locked in and any subsequent conditional orders (see below) are performed; otherwise they are ignored.

The order calling for a change in the order source can be made conditional or unconditional; if conditional it is only performed if the previous sign examination has given an affirmative result. This allows a new set of orders to be brought in when the previous set has brought the calculations to a desired stage.

The order requiring a search for a block-marking character causes all the information to be ignored which lies between the present position on the tape and the specified character. This can again be made conditional on the result of the previous sign examination. Facilities are provided for the tape to be searched in either the forward or the reverse direction, although the tape readers at present available only allow search in the forward direction. The ability to search in reverse will allow sections of the order tape to be used repetitively without necessitating a closed loop of tape.

The print layout is variable to a limited extent. There are ten layouts available for printing each eight digit number, for instance one such layout might consist of the eight digits followed by spaces, and another the eight digits followed by line-feed and carriage return. An order is required to define which layout is to be used, and it stays in force until replaced by another print layout order.

Arithmetical Operations

ADDITION AND SUBTRACTION WITH SINGLE TUBES

As has already been stated, addition is the fundamental operation. Subtraction is effected by adding the complement, and multiplication (or division) by a sequence of multiple additions (or subtractions). The circuits used for adding a number from one store into another therefore form the basis of the arithmetic unit, and are described in detail. Numerical information is handled in the form of trains of up to nine pulses. Each train represents one decimal digit, and as parallel operation is employed there is a separate channel to handle each digit. For normal arithmetical operations the pulses are routed, through a transfer unit, from one store to another, or to the "accumulator." When a digit is being fed from a store to a printer, a "translator" unit is used to convert the train of pulses into a form suitable for operating the relays which control the printer. The same translator is used when reading numerical information into the computor to convert digits stored on relays into trains of pulses. It is connected to the transfer units in exactly the same way as a store, but only handles one digit at a time.

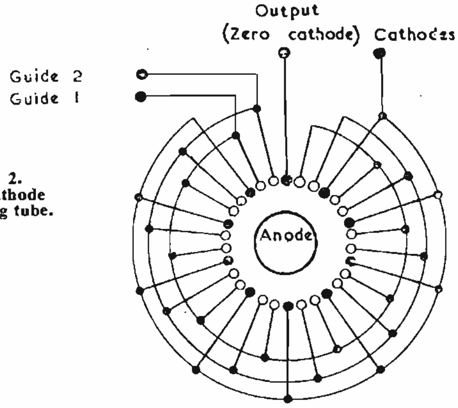


Fig. 2. Cold-cathode counting tube.

It is first necessary to consider the mode of operation of the gas-filled tubes (Dekatrons) which form the basis of the storage system. The arrangement of a Dekatron is shown diagrammatically in Fig. 2. Ten cathodes are equally disposed round a central anode, and all but one are connected together. Between adjacent cathodes there are two guide electrodes, and these are connected together in the way shown.

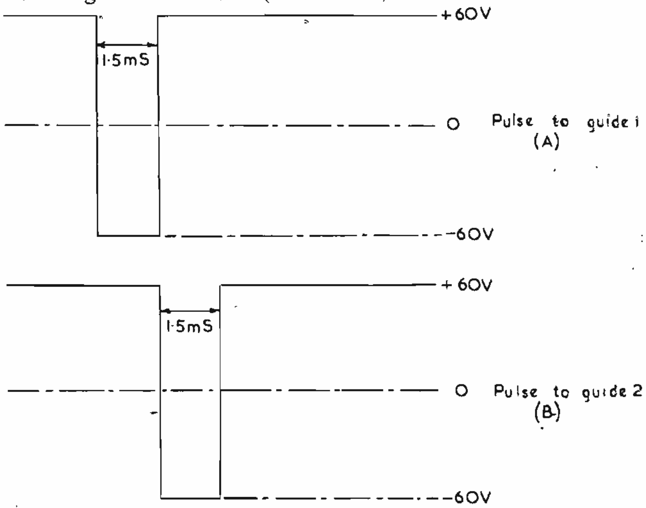


Fig. 3. Pulse to operate counting tube.

Normally the zero cathode is taken through a resistor to earth or to a small bias potential, and the remaining cathodes are earthed. The guides rest at +60V and the anode is connected through a resistance of 1MΩ to +370V.

Pulses of the form shown in Fig. 3 are applied to the guide electrodes to move the discharge from one cathode to the next. During the first pulse the discharge moves to the next guide 1 electrode. At the end of the first pulse the discharge moves on to guide 2, which is then more negative than the previous cathode. At the end of the second pulse, the discharge moves to the nearest cathode, and has advanced one step. It is not necessary for the two guide pulses to overlap, but it is important that any time interval between the end of the first pulse and the start of the second should not be comparable with the de-ionization time of the Dekatron tube. A small overlap has been provided as a precaution against possible failures. If pulses are applied to one guide only, the discharge returns to the same cathode after each pulse.

The method used to pass a digit into the tube is to apply n pairs of pulses of the type shown in Fig.3 to the guide electrodes. The discharge will then advance by n steps, and if the discharge starts from zero, or output, cathode, it will move to cathode n.

To read a digit out of a storage tube, a train of ten pairs of pulses may be applied to the tube, causing the discharge to circulate and return to its starting point. A pulse is produced as the discharge passes the zero or output cathode, and the number of pulses of the train of 10 which occur after the output pulse is an indication of the digit stored on the tube. Further, the number of pulses preceding the output cathode pulse is the complement on 10 of the digit stored in the tube.

The function of the transfer unit is to accept the output cathode pulse from the Dekatron tube from which the digit is being taken (" sending tube "), and from it to derive the pulses representing the digit and complement, either of which is passed to the receiving tube. Fig. 4 is a circuit of one transfer unit, and Fig. 5 shows the waveforms appearing when the digit 3 is transferred. When an addition is to be performed, a relay is energized in a pulse generator unit, which, after a short delay to allow any transients from the relay circuits to die away, produces a train of ten pulses as shown in Fig. 5(a) and 5(b). These pulses are applied to the sending tube, which therefore steps round by one complete revolution. When the discharge arrives at the output cathode, a waveform of the form shown in Fig. 5(c) is produced, and this is used to trigger the cold cathode triode V_1. The cathode potential of V_1 rises from -200 to -160, and the left half of V_2 conducts.

Pulses are applied to the cathode of V_2 synchronously with those shown in Fig. 5(b), but at a different D.C. level, and, prior to V_1 being triggered, they produce negative pulses at the right anode of V_2 (Fig. 5(e)). When V_1 is triggered the pulses appear at the left anode (Fig. 5(f)). It will be seen that the left anode delivers the digit, and the right anode the complement on 10. These pulses are suitable for direct connexion to one guide of the receiving tube. Since, for the purpose of subtraction, the complement on 9 is required, it is arranged that only 9 pulses are applied to the other guide on the receiving tube (Fig. 5(g)) so that the first pulse of the train shown in Fig. 5(e) is ineffective in moving the discharge.

If the sending tube is to be cleared to zero during the transfer, the complement output of the transfer unit is connected to one of the sending tube guides in place of the train of ten pulses. This method of clearing stores is also used when the machine is first switched on, since the Dekatron tubes may light in any position. When the transfer operation is carried out purely to clear a store no receiving tubes are connected, but a dummy circuit (the drain address " 00 ") is connected to simulate a receiving address, in order to satisfy the checking arrangements in the address selecting circuits.

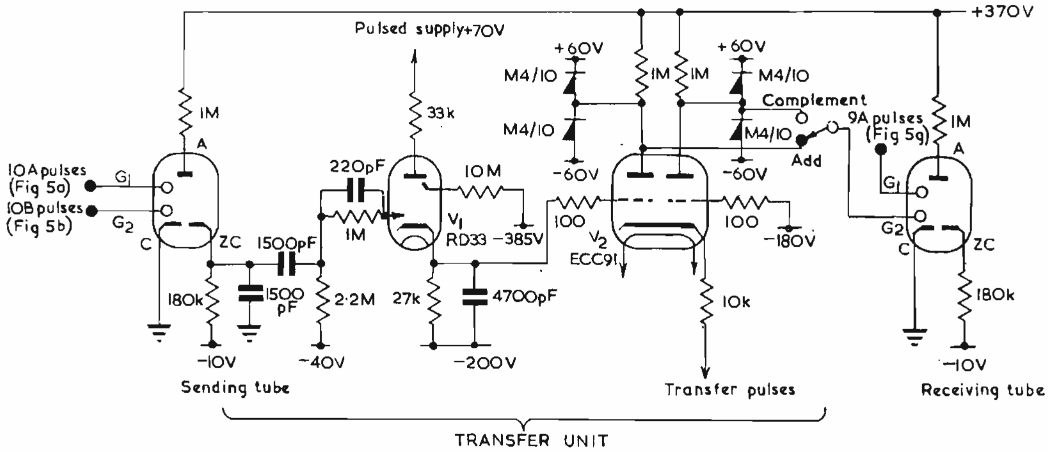


Fig. 4. Transfer circuit

To extinguish V_1 and minimize the chance of spurious triggering taking place, H.T. is removed from its anode from the end of each operation until the start of the next.

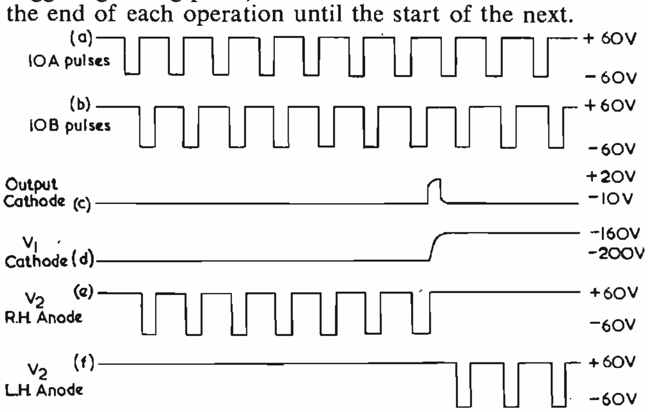


Fig. 5. Transfer circuit waveforms.

Multi-Digit Addition and Subtraction

As well as the transfer circuits described above, circuits are needed to perform carry over, when required, from each digit into the next most significant. The " carry " circuits consist of a cold cathode valve which is triggered when the receiving store reaches or passes zero. This valve remains conducting until the end of the train of transfer pulses, when a second valve performs the carry over and the first is extinguished. A transfer and a carry circuit is required for each digit. Fig. 6 is a diagram showing the connexions for a four-digit store with carry circuits. It will be noted that the most significant tube has a carry circuit, and carry over is made into the least significant tube.

This carry circuit plays no part in handling positive numbers, but is necessary to handle complements. When the complement of a multi-digit number is found, the complement on 10 is required for the least significant digit and the complement on 9 for all the other digits. It has already been explained that in this machine the complement on 9 is found for all digits; there is no simple means of checking electrically which tube in a store carries the least significant figure. Carry over from the most significant tube to the least significant corrects this, as can readily be demonstrated, and enables the complement on 9 to be used in every case, whether in finding the complement of a number or finding the number from its complement.

all carry units indicates that the carry operation is complete. This is arranged to stop the pulse generator and send a " finish " signal to the relay sequence control circuits, which then proceed with the next step.

Means must be provided on each store to show whether the content is a positive number, or a complement (representing a negative number). This could be done by some device (for example a cold cathode trigger valve) having two stable states, but for circuit convenience an additional Dekatron has been used in each store. An additional transfer and carry unit is used, wired so that the sign tube receives the carry over from the most significant tube. Carry over from the sign tube is passed into the least significant tube.

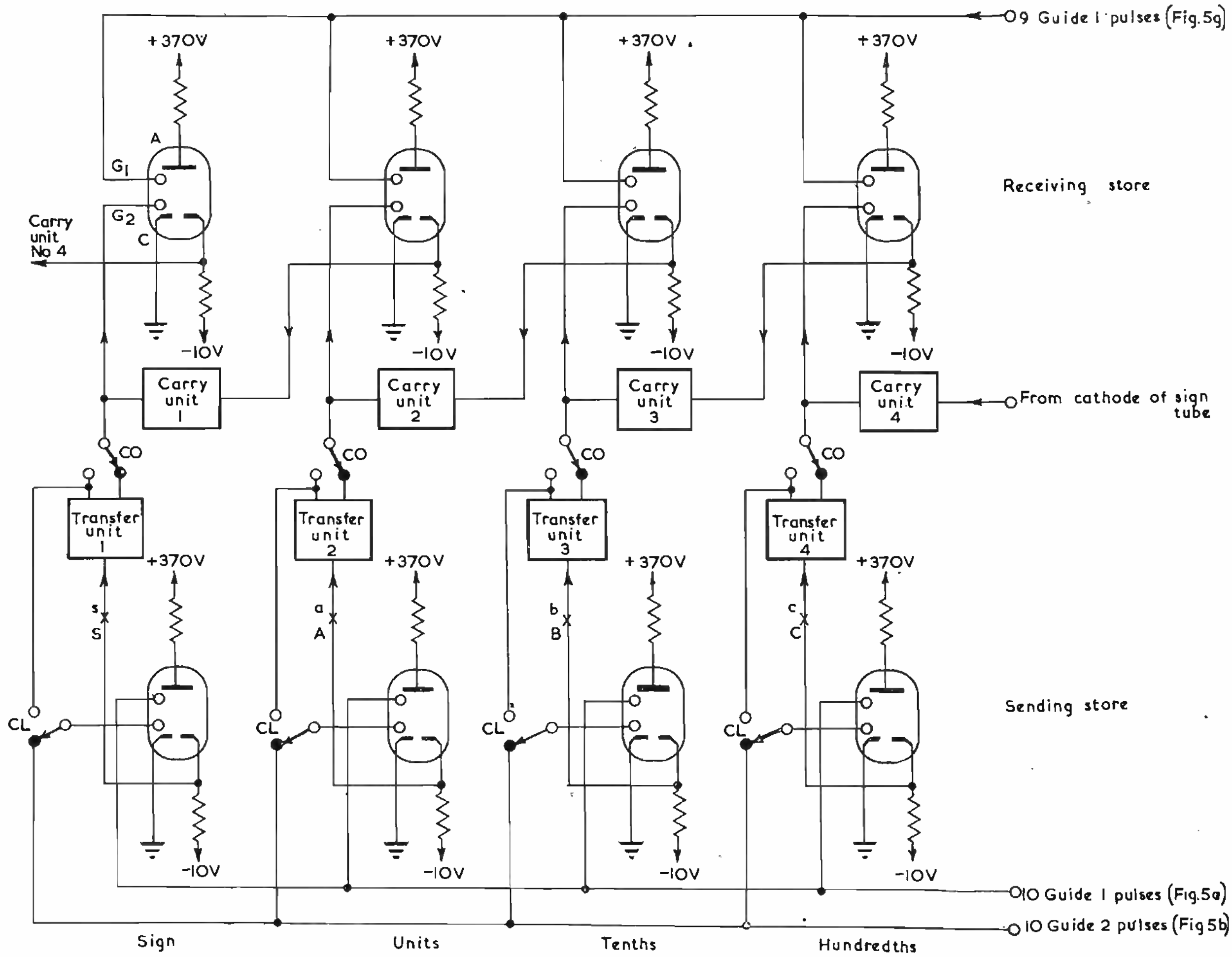


Fig. 6. Arrangement of transfer and carry units for three digit operation.

The arrangement of the carry circuit is shown in Fig. 7. The pulse generator continues to produce the pulses shown in Fig. 5(g) (applied to receiving tubes) after the main train of 9 is completed. It also provides pulses for application to V_4 cathode similar to those applied to the cathode of V_2 in the transfer unit but on a separate wire and beginning immediately after the train of transfer pulses is completed. If the receiving tube connected to V_3 reaches or passes zero, V_3 is triggered, and the potential of the left grid of V_4 is raised. When a pulse is applied to V_4 cathode it then appears at the left anode and is applied to the guide of the next most significant receiving tube. A pulse is applied simultaneously to the anode of V_3, and extinguishes the discharge. Subsequent pulses applied to V_4 cathode appear at the right anode of V_4. The simultaneous appearance of pulses at the right-hand anodes of

For positive numbers the sign tube is at zero, and for complements at 9. A double triode is connected to the output cathode of the sign tube, and this operates two relays corresponding to + and −. The contacts of these relays give sign information required when multiplying, dividing or printing. It is also arranged that a warning is given when this sign inspection circuit is not connected to any tube, perhaps as a result of faulty address selection.

Multiplication and Division

Division necessitates the use of a special store (the accumulator) having 15 digits, since when an 8-digit quotient is to be obtained with an 8-digit divisor, there are cases where difficulties would arise if a 15-digit dividend were not provided. An accumulator of more than eight digits also reduces errors in rounding off the product of multiplication if products are repeatedly summed in the accumulator. A further advantage of a long accumulator is that the remainder after division is available for use it required.

In both multiplication and division one storage address is used as the sending store, the accumulator is connected to the output of the transfer units, and a second storage address is used in a special way, to be described, and is referred to as a register. The contents of these stores are shown in Table I. Circuits are provided to inspect the sign of each of these stores and immediately the addresses have been selected relays connected to these circuits ensure that the arithmetical operations to be performed will result in a product or quotient of the correct sign.

TABLE I

	MULTIPLICATION	DIVISION
SENDING STORE	MULTIPLICAND	DIVISOR
ACCUMULATOR	PRODUCT	DIVIDEND
REGISTER	MULTIPLIER	QUOTIENT

Where the multiplier is positive, the multiplicand is added into the accumulator N_1 times where N_1 is the number stored in the most significant tube of the register (multiplier). A shift to the right is now introduced by the relay shift circuit (i.e., in Fig. 6, point A is connected to b and B to c, points S and a being connected to s), and the multiplicand added into the accumulator N_2 times, where N_2 is the number stored in the second tube of the register. This process of multiple additions alternating with operation of the shift unit continues until the whole of the multiplier is dealt with. In order to perform the correct number of additions, the tube in the register containing the digit of the multiplier being considered is moved back one step (for convenience

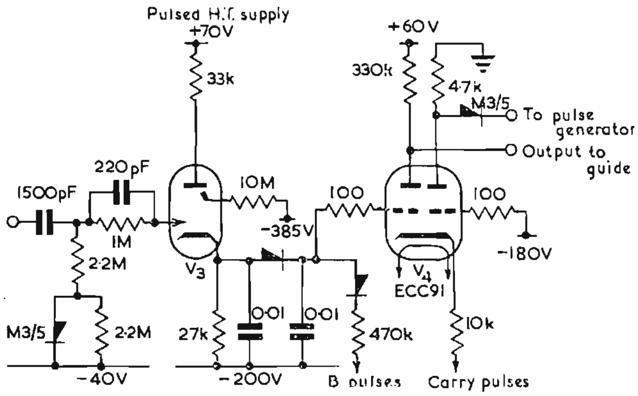


Fig. 7. Carry circuit.

it is actually moved on nine steps without carry over) for each single addition. The pulse generator is arranged to give the finish signal calling for the next operation when the appropriate digit of the register has reached zero and carry over is complete.

When the multiplier is a complement, a similar procedure is carried out with a few modifications. Multiple subtractions are required, and the register tube is moved forward one step for each subtraction. Since the complement of 0 is 9, it follows that transfers should stop when the register tube reaches 9. As the pulse generator allows transfers to continue until the tube reaches 0, one too many will be performed by the time the finish signal is given, and it is necessary to make a single addition to correct for this. The sequence then is multiple subtraction, single addition, operation of shift. These sequences are controlled by relays in the sequence controlling and routing section of the machine. It is, of course, only necessary to give the order "multiply"; the precise sequence required is selected before the operation starts by a relay circuit dependent on the sign of the contents of the selected addresses.

Division is performed by a sequence of the same form, i.e., multiple transfer, single transfer, operation of the shift; the quotient is built up digit by digit in the register by moving the discharge one step forward or backward in the register for each transfer. For a divisor and dividend of the same sign, the divisor is subtracted from the dividend and the register moved forward until the sign of the dividend changes, when the pulse generator gives the finish signal. At this point one subtraction too many has been performed, and this is corrected by making one addition and moving the register back one step. When the divisor and dividend are of opposite sign, the multiple transfers are additions, with the register being moved back step by step and the single transfer is a subtraction. In this case it is not necessary to move on the register during the single transfer, since the fact that it has started from 0 rather than 9, the correct starting point for a complement, means that the necessary correction has already been made.

ROUNDING OFF

After multiplication or division, some form of rounding off is normally needed to avoid a systematic error due to the omission of digits less significant than the least significant held in the stores. In multiplication, rounding off is most conveniently done when the product is transferred from the 15-digit accumulator to an 8-digit store. A method commonly employed is to add five to the most significant of the digits which are omitted in this process; carry over then adds one to the least significant figure retained if the omitted figure was 5 or over. The maximum error in the last digit is ± 0.5, and the average error is zero. This process would have proved inconvenient in the present machine, partly because it would involve the generation of a special train of 5 pulses, but also because in the case of division, the quotient is built up in an 8-digit store, and without much extra complication a 9th digit is not available to be rounded off. Accordingly the cruder method of adding 1 or 0 at random to the 8th figure of the product or quotient has been adopted. The maximum error in this digit is now ± 1, and the average error is zero. The probable error after rounding off in this way is about twice that to be expected from the more conventional process. This error is not considered serious. A more important point is that the random nature of the result makes difficult the precise checking of the machine by repeating a solution in which rounding off had taken place.

To minimize systematic errors the selection of 0 or 1 for rounding off must be as nearly random as possible. The method adopted is relatively simple. A master oscillator in the pulse generator produces continuously the pulses which are subsequently routed to perform the transfer and carry operations. Pulses from this oscillator are fed continuously to a scale-of-two circuit, a pair of cold cathode triodes which conduct alternately. When rounding off into any address the state of the scale-of-two circuit at the beginning of the transfer period determines whether 0 or 1 is transferred in the last digit.

(To be continued)

(To be continued)

REFERENCES

[1] Hartree, D. R., "The ENIAC, high-speed electronic calculating machine." *Nature, 158*, 500-506, 1946.
[2] Burks, A. W., "Electronic computing circuits in ENIAC." *Proc. IRE 35*, 1947.
[3] Wilkes, M. V., and Renwick, W., "The EDSAC, an electronic calculating machine." *J.S.I. 26*, 385, 1949.
[4] Wilkes, M. V., "Programme Design for a High Speed automatic calculating machine." *J.S.I. 26*, 217, 1949.
[5] Kilburn, T., "The University of Manchester Universal High Speed digital computing machine." *Nature, 164*, 684-686.
[6] Williams, F. C., and Kilburn, T., "A storage system for use with Binary Digital Computing Machines." *J.I.E.E.*, III, *96*, 81-100.
[7] Booth, A. D., "A Magnetic Digital Storage System." *Electronic Eng., 21*, 234, 1949.
[8] Booth, A. D., "Physical realisation of an Electronic Digital Computor." *Electronic Eng., 22*, 492, 1950.
[9] Williams, S. B., "A relay computer for general application." *Bell Laboratories Record, 25*, No. 2, Feb., 1947.
[10] Williams, S. B., "B.T.L. Relay Computing Machine." Mathematical Tables and other Aids to Computation. Vol. III, Nos. 21 and 22, Jan. and April, 1948.
[11] Bacon, R. C., and Pollard, J. R., "The Dekatron, a new cold cathode counting tube." *Electronic Eng.*, 22, 173, 1950.

The Design and Operation of Television Cathode-Ray Tubes

By L. S. Allard, B.Sc., A.Inst.P.*

THE requirements of present day television receivers are large, bright, well defined pictures, and needless to say the cathode-ray tube plays a very important role in achieving these requirements. Thus in designing television cathode-ray tubes, the designer has to bear in mind these three qualities, together with others not directly related to the viewer's requirements, such as tube overall length, operating E.H.T. voltage, and scanning power, and design the tube accordingly. It soon becomes apparent that compromises have to be made in order to achieve the optimum design.

Electron Guns

The three main types of gun which can be used for television purposes are:—

(a) Electrostatic focus and electrostatic deflexion.

(b) Electrostatic focus and electromagnetic deflexion.

(c) Electromagnetic focus and electromagnetic deflexion.

The merits of each of these designs will be considered separately, with particular reference to type (c) which is at present the gun design commonly in use.

(a) Electrostatic Focus and Electrostatic Deflexion

This type of tube was in use pre-war in television receivers, but has rapidly lost favour because of several inherent disadvantages. Fig. 1 indicates the form of an "all electrostatic" cathode ray tube, and also the path of the electron beam.

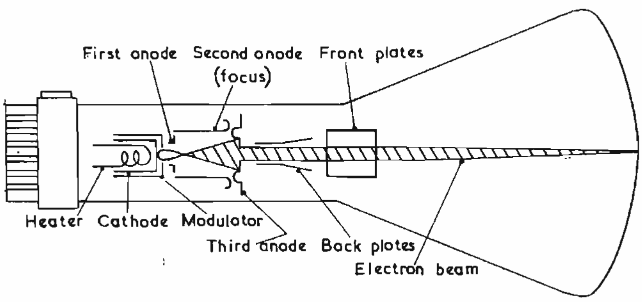


Fig. 1. Electrostatic focus and deflexion

It will be seen that only a fraction of the total current leaving the cathode finally arrives at the screen. This is due mainly to the electrostatic deflector plate design, for if large beam diameters are used, then to ensure freedom from spot distortion upon deflexion, the deflector plates would have to be spaced very much further apart. This would entail an increase in the deflector volts required for a given scan size assuming other parameters remain constant. A further factor to be considered in conjunction with the beam trimming operation is that electrostatic lenses cannot handle very large beams because the lens aberrations cause a deterioration in spot quality. This lower gun efficiency (i.e., beam current/cathode current) means that for a given E.H.T. voltage, one has to tolerate a screen brightness lower than in the case of the "all magnetic" tube, where all the current leaving the cathode arrives at the screen. The brightness level could be restored by increasing the E.H.T. voltage, but this would increase the voltages necessary to scan the tube.

Tube overall length is the other main disadvantage with the "all electrostatic" tube. When compared with the "all magnetic" tube of the same screen diameter, the electrostatic tube is about 50 per cent longer. The reason for this increased length with the electrostatic tube is twofold: firstly the deflecting systems for the two axes are sequential rather than simultaneous, and also the total deflecting angle must of necessity be restricted to approximately 30°. If this scan angle was increased, severe deflexion defocusing would be introduced because of the non-uniform deflecting fields through which the beam would have to pass.

(b) Electrostatic Focus and Electromagnetic Deflexion

This type of tube, shown in Fig. 2, is not used in present-day commercial television receivers, mainly because of its overall length, but it is capable of producing a very fine picture and it is ideally suitable for monitoring purposes. This design, which was employed in wartime radar tubes, has for its main focusing lens the electrostatic field introduced between the lip of the second anode and the internal graphite coating on the neck of the tube. The beam is trimmed on the first anode, although far less severely than in the "all electrostatic" case. It is possible to obtain beam currents comparable with the "all magnetic" tube at the expense of only a small increase in the "drive" voltage applied to the modulator. The beam diameter however is slightly larger than in the normal magnetic tube, and in consequence of this the scanning angle has to be reduced to maintain a uniform focus upon deflexion. To obtain optimum spot quality a considerable amount of care has to be taken on the electrode structure and also on the glass quality in the neck region where the focusing lens is formed.

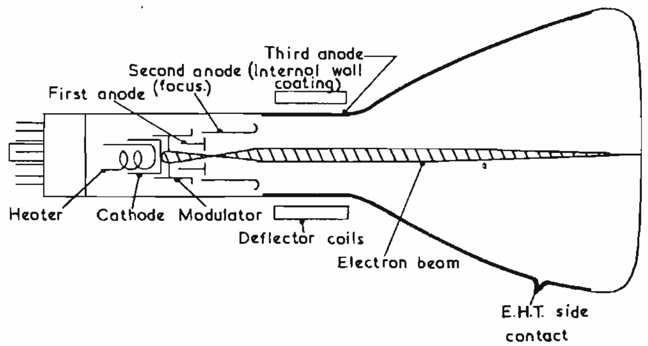


Fig. 2. Electrostatic focus, magnetic deflexion

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

(c) Magnetic Focus and Magnetic Deflexion

Almost all of the television receivers now produced in this country use this type of tube as they afford the best practical compromise between all the characteristics required of the cathode-ray tube. Fig. 3 is an outline drawing of an "all magnetic" tube. It is possible to design this type of gun so that the tube is 100 per cent efficient, i.e., all the current that leaves the cathode arrives at the screen.

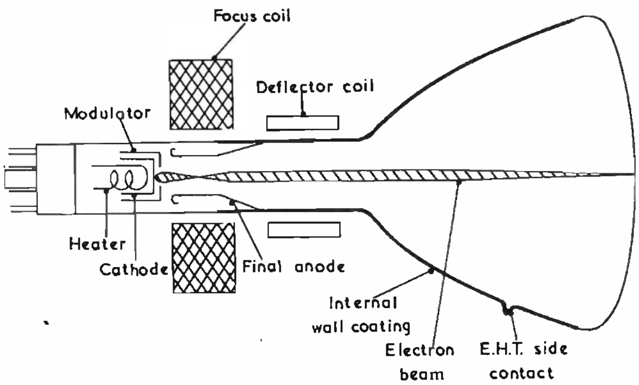


Fig. 3. Magnetic focus and deflexion

Design of "All Magnetic" Tube

It should be understood that every cathode-ray tube is designed as a complete unit, inasmuch that the triode section (cathode/modulator/anode) and the positioning of the final focusing lens and deflecting system all have to be considered together. This immediately places the magnetic tube at a disadvantage when compared with the electrostatic tube. In the latter, the focusing and deflecting electrodes can be carefully designed and positioned inside the glass envelope. All that the user has to do is to apply the correct voltages, and a good result is assured. With the magnetic tube, however, the tube designer has no such control over how the tube will be used. With the varied

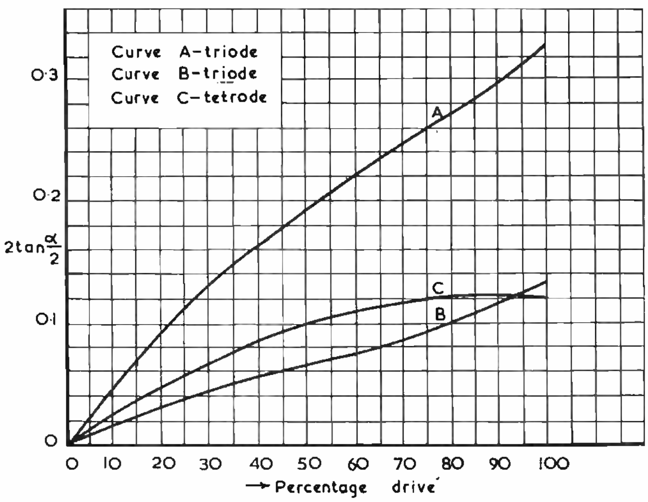


Fig. 4. Relation between beam angle and percentage drive for triode and tetrode guns

range of deflector coils and focusing assemblies available, and the freedom with which these can be positioned, it is not surprising that at times unjust criticism is levelled at the tube.

One of the most important features that has to be considered in the design of electron guns is the diameter of the electron beam at various positions along its path. This beam diameter is governed by the manner in which the electrons proceed from the "cross-over" plane. The "cross-over" plane, as its name implies, is the plane situated in the modulator-anode region where the electrons, after leaving the cathode cross over are focused by the immersion lens in this region. The electrons leave this "cross-over" plane in a divergent cone, the solid angle of which depends upon the electrode geometry and the percentage "drive" applied to the modulator. (The percentage "drive" is the percentage ratio of the modulator volts excursion from "cut-off" to the "cut-off" voltage.) Curves indicating the relationship between the percentage "drive" and the divergent angle of the cone of electrons for triode and tetrode guns are shown in Fig. 4. These curves have percentage "drive" for their abscissa, and $2 \tan\alpha/2$ for their ordinate, where $\alpha/2$ is half the divergent angle. It will be seen that the solid angle increases with increasing "drive" voltage.

The two most common forms of electron guns used for magnetic tubes are the triode and tetrode assemblies. The triode consists of a cathode, modulator and anode to which the main E.H.T. is applied, while the tetrode has an extra anode between the modulator and main anode. To this extra anode a potential of a few hundred volts is applied, and it is this potential which governs the grid base of the tetrode tube, i.e., the modulator voltage required to suppress the emission. One point often quoted in favour of the tetrode gun is that the tube may be

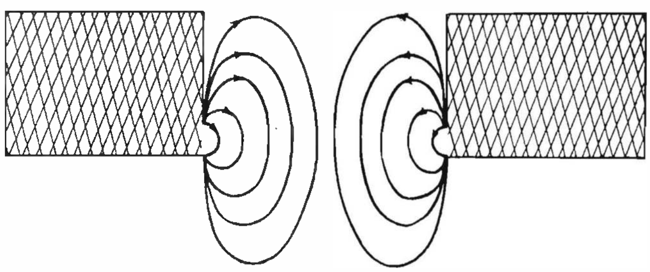


Fig. 5. Magnetic focusing field

operated over a wide range of final anode voltage, thus controlling the tube brightness, without interfering with the grid base. This is perfectly true provided that the tube is always operated with the correct design voltage applied to the first anode. Unfortunately this is not always adhered to in practice, a variation of as high as 2:1 in voltage applied to the first anode not being uncommon. This would entail an approximate 2:1 variation in the grid base of the tube. In order to obtain a comparable grid base variation for example on a 6kV triode tube, it would have to operate at approximately 12kV—a range in E.H.T. certainly not expected to be encountered. Constructional difficulties and tolerances on both types of tube are comparable, the triode assembly having perhaps a slight advantage in that there is one electrode less than in the tetrode case.

It would appear that there is a far greater possible variation in beam angle with the triode than with the tetrode when considering alterations in gun geometry. Fig. 4 indicates two beam angle curves, A and B, obtained with triode guns of differing geometry, while curve C indicates the type of curve obtained with practical forms of tetrode geometry.

Focusing

The divergent cone of electrons proceeding from the "cross-over" plane then encounters the main focusing lens, which focuses the beam on to the screen to form an image of the "cross-over" region. This main focusing lens can be obtained by either a permanent magnet or an electro-magnet, producing a field as shown in Fig. 5. The electrons, possessing axial and radial components of velocity, encounter the radial and axial components of the focusing field, the resultant effect of which is that the electrons spiral in the focusing field and finally arrive at the screen to produce a small well defined spot. Experiments with a cathode having lines scribed upon its surface indicate that the angle through which the electron beam spirals in the focusing field is about 80°.

Fig. 6 represents a common form of electro-magnet suitable for television tubes. The field strength can be adjusted quite easily by varying the current flowing through the coil, and this affords the means of a simple adjustment as the users control to maintain the picture in good focus without altering any other of the tube's characteristics. Considering receiver economics however, the television set manufacturer has to provide a current to flow through this coil, and so the use of permanent magnetic focusing systems is becoming more popular. This latter method of focusing, as compared with the electro-magnetic methods, does not allow such an easy form of focus adjustment to be made, which might be required with any variations in the tube E.H.T., caused for example by mains voltage fluctuations.

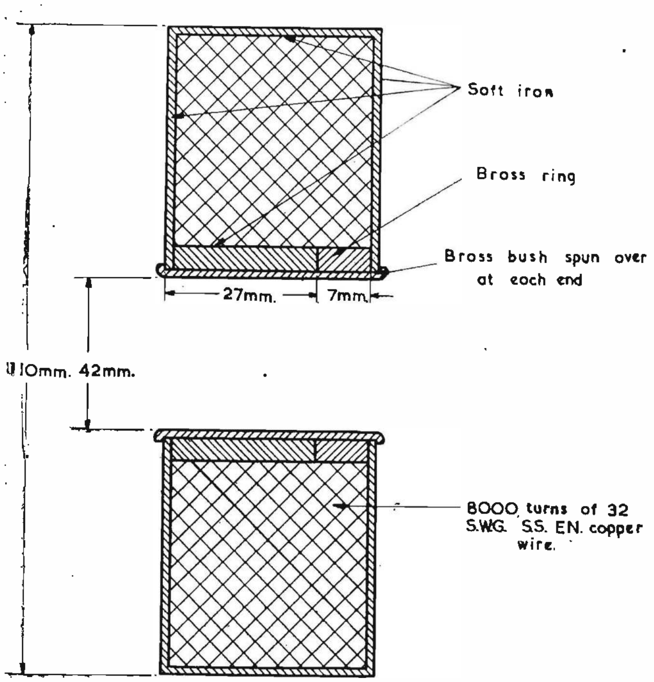


Fig. 6. Typical electromagnet for use with C.R.T.

It is important that the focusing field should be located in the correct position relative to the electron gun, otherwise the operation of the tube may be impaired. As in geometrical optics, the magnification is proportional to the ratio of image distance to object distance. In the cathode-ray tube the object distance can be taken as the spacing between the modulator and the mid-plane of the air gap across which the focusing field is developed. Thus a considerable variation in spot size is obtainable by altering the focus field position. A further disadvantage with moving the focusing field is that the beam diameter may be varied in the deflector coil region, thus introducing deflexion defocusing. This effect can be most marked especially if a beam is used having a large divergent angle, as is sometimes employed when exceptionally good definition is required.

Ideally, to obtain the best spot quality, i.e., freedom from astigmatism and other spot distortions, it is important that the axis of the electron beam should coincide with the axis of the focus coil. Due to inaccuracies in the electrode assembly and also in sealing the system into the bulb, it does not follow that the beam axis is coincident with the tube axis. Consequently it is not sufficient just to ensure that the focussing assembly is co-axial with the tube neck for the electron beam can still be travelling off the tube axis. No method of ensuring correct alignment with a permanent magnet system immediately suggests itself, although it is possible to do so with the electro-magnetic assembly. The procedure adopted would be as follows:—

(a) Observe the position of the spot with no current passing through the coil and also the two focused positions with the current flowing in opposite directions.

(b) Adjust the position of the coil both by displacements transverse to the axis and by tilt about axes perpendicular to the tube axis until the three spot positions noted under (a) are coincident. Under these conditions the beam and focus coil are co-axial. (Note: It is not sufficient in the above test to pass the current through the coil in one direction only, the current must be reversed.)

It is important to realize that the purpose of this procedure is not to centre the picture on the tube face, but to obtain accurate alignment of the focus coil with respect to the beam. Picture centring will be considered later.

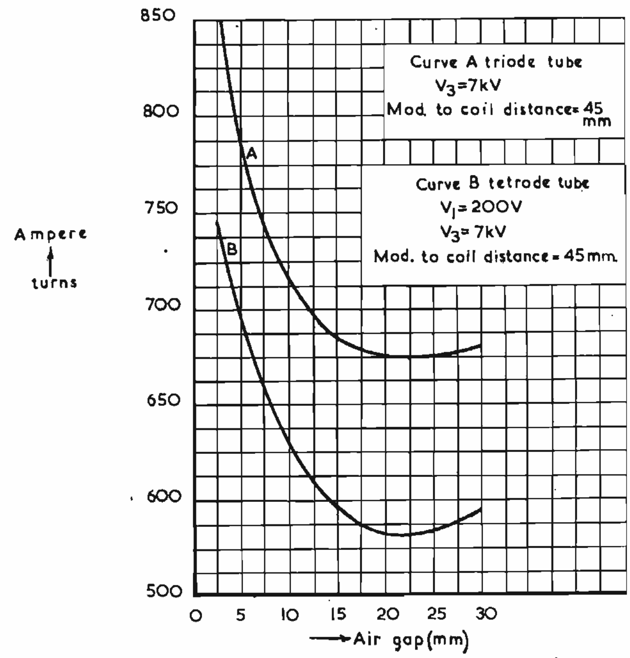


Fig. 7. Relation between focus coil air-gap and ampere-turns for 12in. triode and tetrode tubes

An empirical relationship obtained with an electro-magnetic focus coil on a triode tube, is that the ampere-turns, and the hence field strength, required for focusing are proportional to $\sqrt{(V_3/q)}$, where V_3 is the tube E.H.T. and q is the distance between the modulator and the mid-plane of the focus coil air-gap.

The field strength required for focusing triode and tetrode tubes, when they are operated under the same E.H.T. and with the focus coil in the same relative positions, are different, the tetrode tube requiring a lower field strength than the triode. This is due to the different object distances connected with both tubes, that for the tetrode being larger in virtue of the electrostatic lens action between the first and second anodes. This lens forms a virtual image of the "cross-over" plane on that side of the "cross-over" plane farthest from the focusing lens. This difference in field strengths is again quoted as a point in favour of the tetrode tube, especially if electro-magnets are used. However, this assumes the use of idential coils in the two cases, and it can be shown that by employing slightly different air-gaps in the focusing systems used with the two tubes, the ampere-turns required can be made equal. Fig. 7 is a graph relating the ampere-turns required for focusing both triode and tetrode tubes with varying focus coil air-gaps. Both tubes were operated with the same E.H.T. and the same focus coil position. It will be seen that as the air-gap is increased the graphs for both types of tube reach a shallow minimum in the region of 20mm gap. It was found however that with the coil used some deterioration of spot quality was encountered if a gap size larger than about 18mm was employed. Nevertheless it is possible to choose suitable air-gap values for the two types of tube in which the ampere-turns are identical.

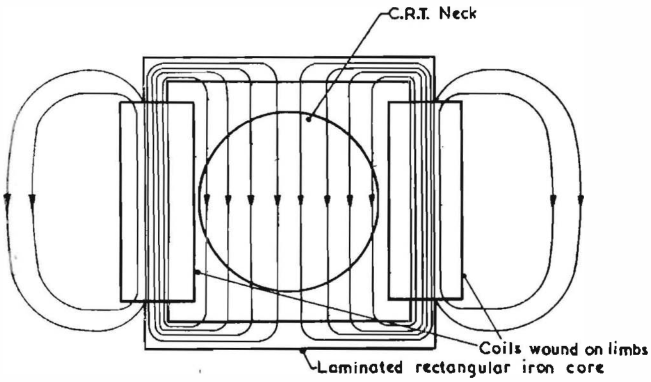


Fig. 8. Rectangular iron-core coil producing uniform deflecting field

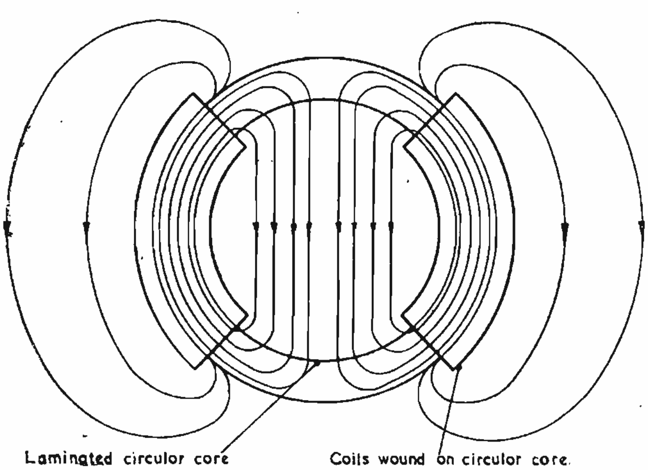


Fig. 9. Toroidal wound iron-core deflecting coil

Deflexion

Having obtained a focused beam of electrons, it is then necssary to deflect it in two perpendicular directions to obtain the rectangular raster. For this purpose, two pairs of deflector coils are used, producing crossed fields. The characteristics required of scanning coils for good television pictures are:—

(a) Linearity of scan.

(b) Perfectly rectangular raster.

(c) Freedom from deflexion defocusing.

If any of these three factors is not maintained, then the picture quality may deteriorate appreciably. In addition to these three requirements, the set designer requires the coils to have as high a sensitivity as possible together with certain inductance and resistance values to simplify the scanning circuits.

The range of coil designs available to the tube user is extensive, each different type having its own particular characteristics. Unfortunately there is no well founded theory which can be generally applied to deflector coil design to ensure the successful operation of the tube. Ideally each type of tube should have deflector coils specially designed to obtain the optimum performance. It is known that the deflexion defocusing properties of a tube are dependent upon the beam diameter in the deflector coil region, the deflexion defocusing deteriorating with increasing beam diameter. With beam diameters in the deflector coils greater than about 3mm, the design of the coils becomes more critical, especially with tubes having a screen with a large radius of curvature.

The compromise that has to be decided upon in an optimum coil design for a given beam diameter is between scan distortion i.e. "pin-cushion" or "barrel" distortion and deflexion defocusing. Both of these qualities are dependent upon the uniformity of the deflecting field.

Uniform deflecting fields may be obtained with iron core coils as indicated in Figs. 8, 9 and 10. The coils shown in Fig. 8 are inefficient as some of the energy is expended in the corners of the rectangular yoke, and thus contributes nothing to the beam deflexion. To improve the efficiency, either toroidal or slotted iron-core coils may be used, as shown in Figs. 9 and 10. However, due to the

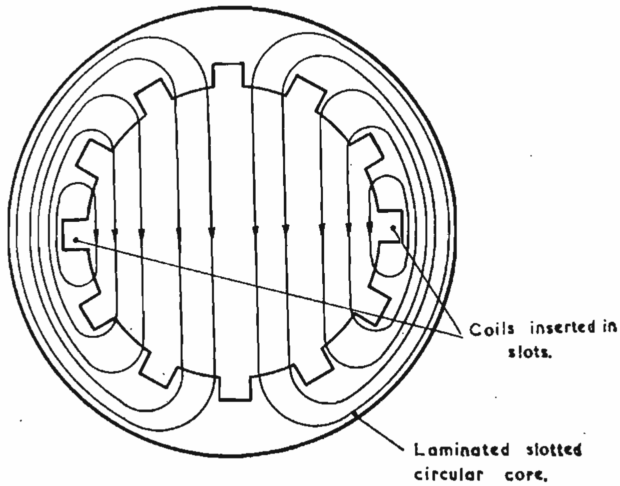


Fig. 10. Slotted iron-core deflecting coil

magnetic path length in air varying across the tube neck the coil turns have to be specially graded to ensure a uniform field. It has been shown[1] that to obtain a uniform field with these types of coils the density of the windings must be proportional to cos θ, where θ is the angle measured from the direction of deflexion of the beam. In practice it is usual to make approximations to the cosine distribution of density of windings.

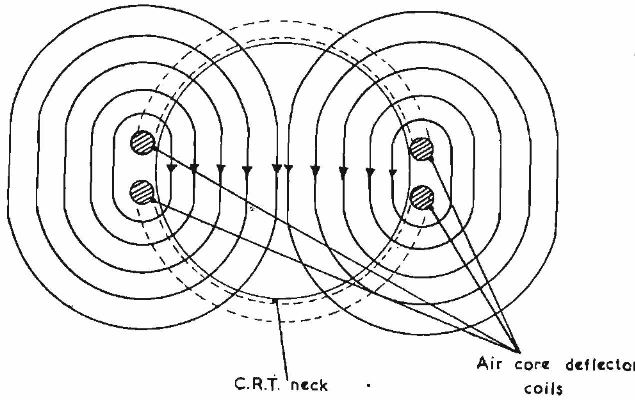
The electron beam follows a circular path in the magnetic deflecting field, and then on leaving the field it continues to travel in a straight line which is a tangent to the curved path at the point of exit. The angle which this tangent makes with the horizontal is directly proportional to the deflecting field strength. Therefore with a uniform deflecting field, it should only be possible to obtain a distortion free raster on a screen having a radius of curvature equivalent to the distance between the mid-point of the coils and the screen. If such a field were used for example with a flat screen, then the raster would become non-rectangular, and assume a "pin-cushion" shape. To overcome this defect, the deflecting field should be purposely distorted. In the particular instance cited above, i.e., the obtaining of a rectangular raster on a flat faced tube, the magnetic lines of force in a plane perpendicular to the tube axis need to be of "pin-cushion" form, and this can be done by increasing the density of turns at low values of θ and/or decreasing the density of turns at high values of θ. The amount of departure from the cosine distribution will, of course, have to be determined by experiment.

Although these coils can be relied upon to give very good results, they are very seldom used in television receivers because of their relatively high cost of manufacture. Thus it is very common to find the cheaper air-cored coil used in television receivers. Deflexion in each of the two perpendicular axes is obtained by suitably connecting two "saddle" shaped coils. Fig. 11 indicates the form of this type of coil. It is also usual to surround the coils with a magnetic return path of low reluctance consisting of soft iron semi-circular laminations or wire. This reduces the stray external magnetic field surrounding the coils and improves the field inside the tube.

The cosine density of distribution for obtaining uniform fields also applies to these air cored coils, although for ease of manufacture, many approximations are employed. Firstly, the grading is seldom carried beyond $\theta = 45°$ to enable the close fitting of the coils around the tube neck thus ensuring greater sensitivity. Secondly, in obtaining the required distribution of windings, rather than wind individual coils of various turns, it is customary to wind the complete coil on a single former, using wires of differing gauge. Thus for example an approximation using three wire gauges may be used, and it is a relatively simple operation in the coil winding process to change the wire gauge after a certain number of turns have been applied. The number of turns used in the above method will of course have to be determined experimentally on each particular design of tube.

Care needs to be taken with the end turns of the coils, for these contribute nothing to the required beam deflexion, and can cause harmful results such as defocussing. Improved performance is usually obtained when these end turns are taken as far away from the tube neck as possible.

To improve sensitivity the deflector coils are usually made as long as possible, the limit being when neck shadowing is introduced. It is a good working approximation to assume that the beam, when deflected, emanates from the mid-point of the deflector coils. Thus it is always possible



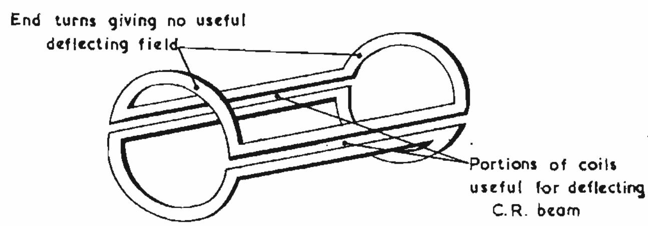


Fig. 11. Air-core deflector coils

to specify a centre of deflexion with each type of tube, which should not be exceeded if neck shadowing is to be avoided. For 9 in. tubes of existing design, whose bulb dimensions are approximately similar, the centre of deflexion should not be more than 25mm back from the standard reference line in the shoulder region.

Bulb Shape

The only major difference in the bulb shapes used by various tube manufacturers which can have an appreciable effect on picture quality, is the curvature of the screen, and this has already been discussed in the previous section.

One real advantage of flat faced tubes over tubes having curved screens is the larger viewing angle which it affords,

Table 1

Relationship between Picture Quality, Coil Grading, Beam Diameter and Tube Face Curvature, keeping the Anode Volts and "Drive" Constant.

Tube	Graded Coils		Non-Graded Coils	
	Flat Screen	Curved Screen	Flat Screen	Curved Screen
Large Beam Diameter (e.g. 8 mm)	1. Good Focus Uniformity 2. Pin Cushion Distortion 3. Small Spot 4. Large Angle of View	1. Good Focus Uniformity 2. No Scan Distortion 3. Small Spot 4. Limited Angle of View	1. Poor Focus Uniformity 2. No Scan Distortion 3. Small Spot 4. Large Angle of View	1. Poor Focus Uniformity 2. Barrell Scan Distortion 3. Small Spot 4. Limited Angle of View
Small Beam Diameter (e.g. 3 mm)	2. Pin Cushion Distortion 4. Large Angle of View	1. Good Focus Uniformity 2. No Scan Distortion 3. Increased Spot Size 4. Limited Angle of View	2. No Scan Distortion 4. Large Angle of View	2. Barrel Scan Distortion 4. Limited Angle of View

thus enabling one to stand right off the tube axis without losing any of the picture detail. Comments have been made occasionally concerning flat faced tubes and deflexion defocusing, in which it has been stated that the defocusing of the beam upon deflexion is to be expected with a flat screen. The depth of focus however is sufficiently great to compensate for the various screen curvatures used on present day tubes.

The choice of the tube screen curvature is not a really serious source of trouble to the tube designer, for it is always possible so to design the gun to give a satisfactory beam diameter, which, in conjunction with suitable deflector coils will produce a picture free from unbearable distortions. The decision on screen curvature is really ultimately dependent upon economics. It is natural of course, that the more flat the screen is, the thicker does the glass have to be to withstand the total force due to atmospheric pressure. Thus for a 9in. tube the total force on the tube face is approximately $\frac{3}{8}$ ton, while for the 14in. tube the total force is approximately 1 ton. With this latter size of tube a flat pressed screen would probably have to be approximately $\frac{1}{2}$in. thick, a thickness which would certainly make the tube heavy and cumbersome to handle. There would also be imposed certain difficulties in the glass pressing operations in obtaining screens free from any defects.

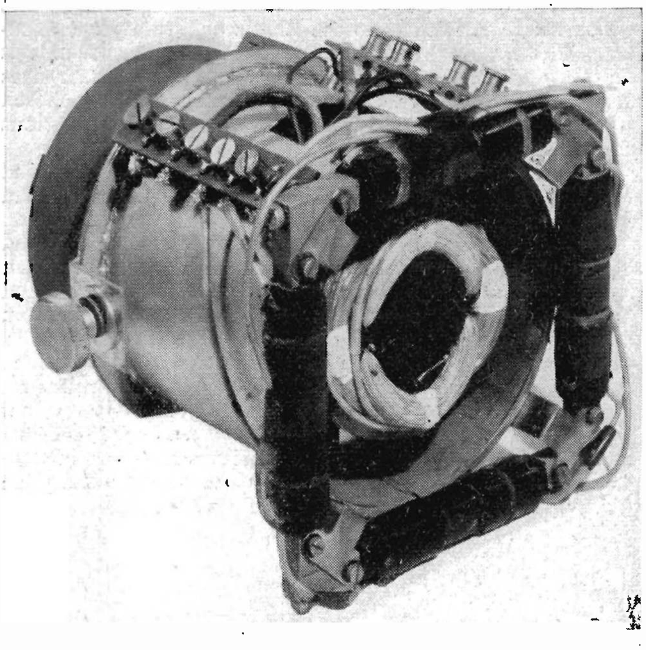


Fig. 12. Separate shift coils wound on rectangular stampings

Table I gives the results to be expected when the three parameters, screen curvature, beam diameter, and coil grading are varied.

Picture Centring

It is possible, due to inaccuracies, both in system assembly and gun "seal-in" in the neck tubing, that the non-focussed, non-deflected electron beam does not bombard the geometrical centre of the tube face. Due to this misalignment and also to the asymmetrical nature of the television picture waveform, it is practically always necessary to centre the raster in the surrounding picture mask. The method which is usually adopted in British television receivers, again because of cost considerations, is to tilt the focussing assembly. From electron optical considerations, this is a bad procedure, and can only result in a deterioration of spot quality. The recommended method of centring would be either by passing some D.C. through the deflector coils, or else by having some separate shift coils which can centre the picture on the tube face after the beam has passed through the normal deflector coils. The controls for picture centring could all be pre-set, and, once having been adjusted for a particular tube, should need no further attention. Fig. 12 is a photograph of an assembly showing the separate shift coils wound on the rectangular stampings, which follow the normal deflector coils.

Conclusions

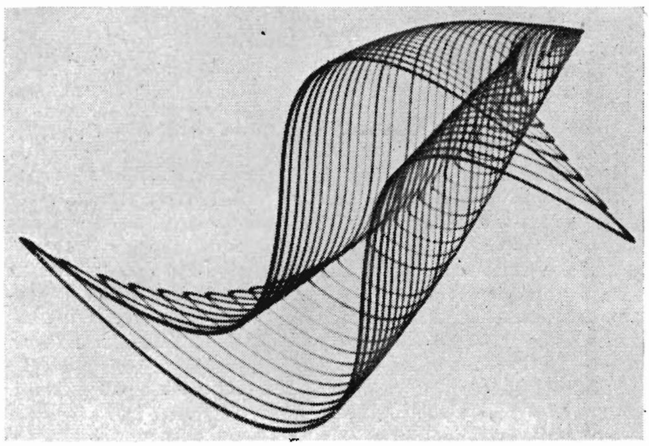
An attempt has been made to outline the reasons why certain types of electron gun are used in present day commercial cathode-ray tubes, and recommended methods of use of the tubes to obtain optimum performance have been given. It will be seen however, that in the majority of cases, the deciding factor has been one of economics. It is true that if television is to become popular and brought within the means of every home, the cost will have to be reduced. To do this, techniques have been adopted which are not wholly beneficial to the operation of the cathode-ray tube. The risks taken so far have probably been warranted, for the effects caused are not so easily noticeable on the smaller size of tube such as the 9in. which has been used in large quantities in this country up to the present time. However, with the advent of larger tubes, where viewers either cannot or will not view from the correct viewing distance, it is quite likely that the operating techniques at present employed will have to be modified in order to obtain the high quality picture that will be demanded.

The original manuscript for this article was written a year ago and, during this time, the use of an electrostatically focused magnetically deflected tube has been announced in America. This American tube, however, employs a focusing arrangement different from that described in the text.

REFERENCES

[1] A. Waroncow, *J.I.E.E. 93*, Part IIIA March-May, 1946, Page 1546. Iron-Cored Deflecting Coils for Cathode Ray Tubes.

A Three-Dimensional *B-H* Loop Display



The above photograph, taken in the G.K.N. Research Laboratories, shows a three-dimensional display of a family of 50c/s B-H loops for 0.014in. Stalloy transformer sheet.

The display, which was produced on a cathode ray tube, illustrates the growth of the B-H loop as the peak induction is increased from zero to 13 kilogauss.

X-rays Applied to the Manufacture of Low Temperature Coefficient Quartz Crystals

By J. R. Halsall.

IN view of the many thousands of low temperature coefficient quartz crystals in daily use, it is surprisingly difficult to obtain easily understood information about their properties, applications, and manufacture.

It is the aim of this article to describe in the simplest possible manner how some of the various types were derived and the way in which precise manufacturing tolerances are maintained by means of x-rays.

Before commencing any discussion on quartz crystals it is necessary first to examine the ideal shape of a natural crystal.[1] Describing it in mathematical terms, it can be said to be a hexagonal prism terminated in two hexagonal pyramids, it possesses one axis of trigonal (threefold) symmetry called the Z axis, and three axes of digonal (twofold) symmetry called the X axes, and in addition has two small facets associated with each face of the prism, the relative positions of which determine whether the crystal be classed as right or left handed as shown in Fig. 1.

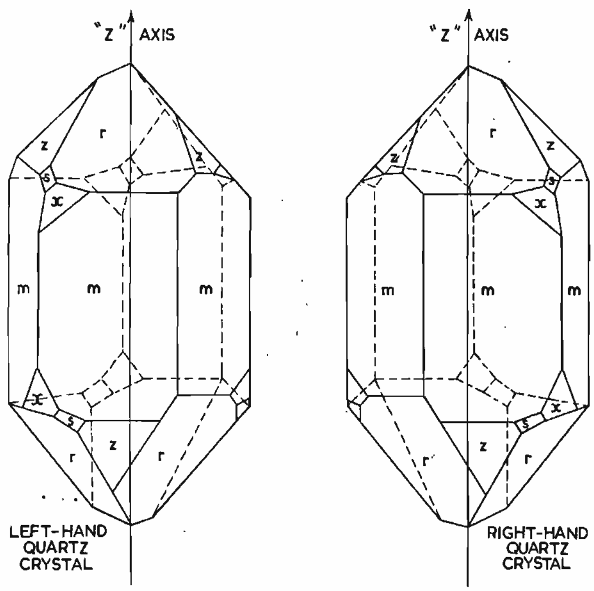


Fig. 1. General form of Quartz crystal

It will be clear from Fig. 1 that the hexagonal pyramid terminations are not regular, the faces being alternatively large and small, the larger ones being designated *r* faces and the smaller ones *z* faces. The faces of the hexagonal prism are called *m* faces, and whereas one end of the *m* face terminates in an *r* face the other end must of necessity terminate in a *z* face. The *m* faces directly below the *r* faces may be called "positive" *m* faces, and those below the *z* faces may be called "negative" *m* faces, so that if we rotate the crystal about the Z axis we will see alternately "positive" and "negative" *m* faces. It is clear from what has gone before that inverting the crystal will involve reversing the sign of the *m* faces, for those which previously lay below *r* faces will now lie below *z* faces and vice versa. This positive and negative classification is nevertheless of great value in the actual cutting of the crystal into slices, as will be seen later.

Three arbitrary axes not yet mentioned are the Y axes which lie perpendicular to the Z axis and pass perpendicularly through any two opposite *m* faces, one Y axis is shown in Fig. 2, which also shows the X axes. The Y axes have no crystallographic significance and are merely chosen for convenience in specifying the orientation of the various crystal cuts.

The Z axis is sometimes called the optical axis, and similarly the X and Y axes are called the electrical and mechanical axes respectively.

The earliest crystal cuts in general use were the X, and Y cuts, so called because the X cut was cut normal to an X axis, and the Y cut normal to a Y axis. The X and Y cuts remained popular for many years but suffered from the disadvantage of having high temperature coefficients, which necessitated the use of thermostatically controlled ovens in all applications where accurate frequency control was required. It was thought by many investigators that crystal cuts having low temperature coefficients and low coefficients of coupling could be developed, and this led to the appearance of the many types in use today, notably the AT, BT, CT, DT, ET, FT, GT. MT and NT cuts.

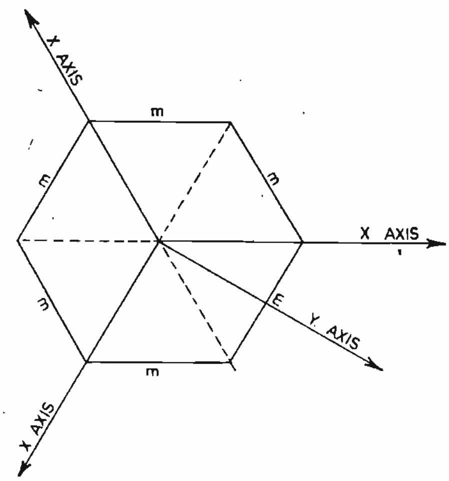


Fig. 2. Section of Quartz crystal normal to Z axis showing location of X and Y axis and *m* faces

These cuts were derived in most cases theoretically by investigating the properties of crystal cuts rotated about the X axis (in the ZY plane) at angles between $\pm 90°$ from Z or Y, so that the X axis lies in the same plane as the finished crystal plate as shown in Fig. 3. The reason will now be clear as to why it is permissible for the same *m* face to be designated both positive and negative, for as can be seen from Fig. 3 both positive and negative angles of cut can be derived from a single *m* face. The saw entering the right-hand *m* face in quadrant A would make a positive cut, which could equally well be obtained by the saw entering the left-hand *m* face in quadrant C. In the same way negative cuts could be obtained by entering the right-hand *m* face in quadrant D or entering the left-hand *m* face in quadrant B.

Before examining the properties of these rotated crystal cuts it is necessary to consider the modes of vibration present in the simpler quartz crystal cuts. High frequency X cut crystals vibrate predominantly in the thickness mode, while low frequency X cut crystals mainly employ the longitudinal mode, both these modes falling into the extensional class. The Y cut crystals, on the other hand, employ the thickness—shear mode of vibration. Unfortunately it is not possible to arrange for these crystals to vibrate only in the single mode desired, for owing to elastic couplings within the crystal matrix,[2,3] numerous other modes will be present at frequencies which may be inconveniently close to the required one. Although these spurious resonances can be greatly reduced by careful dimensioning, their presence complicates the design of crystals using these cuts, and the effect is particularly serious in the case of the Y cut.

By rotating the angle of cut of the crystal about the X axis it is found that at two well defined angles the elastic couplings to the unwanted modes become zero, and at either of these angles one single mode of vibration can be isolated.[4] These cuts are known as the AC and BC cuts and lie at $+31°$ and $-59°$ respectively. These are important angles for if a curve be plotted showing angular rotation against frequency constant (the product of frequency and thickness), it is observed to be almost sinusoidal, with the BC and AC angles being co-

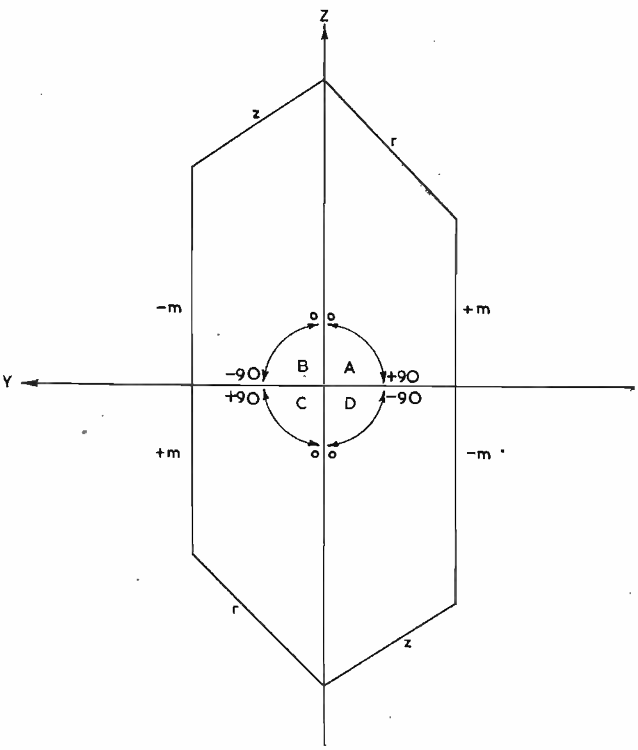


Fig. 3. Section through Quartz crystal normal to X axis showing how rotated cuts are made

ordinate with the maximum and minimum points. Hence for any given frequency the BC is thicker than the AC, and would therefore be more suitable for the higher frequencies where the AC becomes necessarily thin and fragile. Unfortunately the AC and BC cuts have poor temperature characteristics and are therefore rarely used in practice. It was also discovered that rotating the angle of cut yields two definite angles at which the temperature coefficient of the crystal is zero over a certain range and small outside that range. These cuts are the AT and BT cuts and lie at about $+35°$ and $-49°$ respectively. The precise figure depending upon working temperature. These are shown on Fig. 4 together with the AC and BC cuts.

It will be observed from Fig. 4 that the AC and AT and the BC and BT cuts are cut at angles fairly close together. In general for applications such as aircraft radio operating in tropical areas where the range of ambient temperature is necessarily great it is found preferable to employ the AT and BT cuts with their very good temperature characteristics and to tolerate the small amount of elastic coupling to spurious modes which is present, for this effect can be minimized by suitably dimensioning the finished crystal plate. Typical temperature/frequency-drift curves for the AT and BT cuts are given in Fig. 5, the AT having a slightly positive coefficient, and the BT a slightly negative

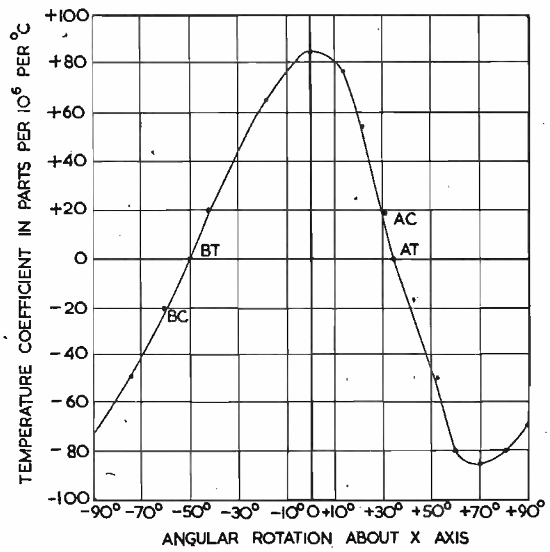


Fig. 4. Relation between angular rotation about X axis and temperature coefficient

one. These curves depend very critically upon the angle of cut, slight discrepancies displacing the "turn-over" point along the temperature axis and larger discrepancies eliminating the zero coefficient property altogether. It is found in practice that 1′ error in angle of cut will displace the "turn-over" point by about 1° along the temperature axis.

No great difficulty would be experienced in keeping to the required tolerance of about $\pm 5'$ even using purely optical methods if crystals as perfect as those shown in Fig. 1 were available. Unfortunately such crystals have

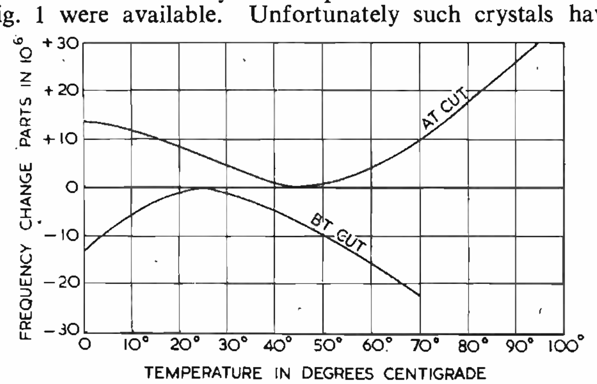


Fig. 5. Typical temperature/frequency drift curves for AT and BT cuts

rarely been seen, and those which are commonly encountered in production may have no exposed faces at all, being rough hewn from the quarry, or waterborne and embedded with sand. X-ray diagnosis has proved to be the only satisfactory method of obtaining the close tolerances required, and crystals can be produced this way in large numbers with cutting errors as low as 5′.

The term reflexion will hereafter be used to describe x-ray diffraction as the results are in this case identical.

x-ray reflexion differs from light reflexion, however, in that it will only be of maximum intensity at certain specified angles which satisfy "Braggs' Law." This is given as:—

$$n.\lambda = 2.d.\ \sin\ \theta$$

and is illustrated in Fig. 6. Here we have two parallel layers of atoms a distance d apart, onto which two x-rays x and y are projected at angle θ, the two rays being exactly in phase at the wave front AB. At this point ray x is reflected from A in layer (1), while ray y continues to C

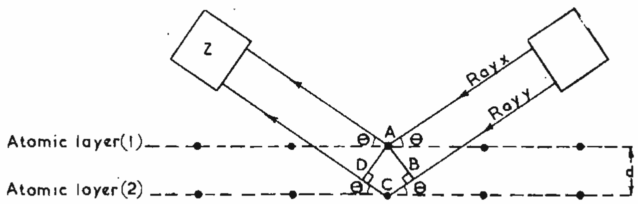


Fig. 6. Illustration of Bragg's law

in layer (2) where it is reflected and appears once more parallel to ray x along the wave front AD. Providing that the distance BCD is a whole number of wavelengths, i.e., $n\lambda$, the two rays will emerge once more in phase and will have a cumulative effect upon a detector placed at Z. If BCD is not a whole number of wavelengths and they emerge out of phase they will detract from each other and the effect at Z will be very much less. Since the distance BSD is obviously equal to $2.d.\ \sin\ \theta$, then the relationship $n\lambda = 2.d. \sin\theta$ applies, and the "Bragg-Angles" unique to a particular layer spacing can be calculated for any given x-ray radiation.

There are large numbers of different atomic layers in quartz and the crystallographer selects only those conveniently near to the desired angle of cut, he then calculates the Bragg Angles, and relating these to the difference between the angle of the atomic layer chosen, and the angle of cut desired, he can then readily calculate the angle at which the x-ray beam will have to strike the crystal specimen for reflexion to occur. In this way sets of results for all the atomic planes commonly used in crystal analysis can be tabulated and the x-ray equipment safely left in the hands of a relatively unskilled operator.

Most x-ray units used in quartz crystal work employ tubes with copper anodes operated at about 50kV, which gives forth a predominantly Cu-Kα radiation of wavelength approximately 1.54 angstrom units. There is also present a certain amount of Cu-Kβ radiation which is usually filtered off with nickel filters, since having a wavelength of about 1.39 angstrom units it can give rise to undesirable errors because the Bragg angles for Cu-Kβ will therefore differ from those for Cu/Kα

The radiation is passed through a collimator to confine it into a ribbon-like beam which projects at a fixed angle onto a rotatable specimen holder. The reflected ray is detected by means of an ionization chamber usually containing methyl-bromide gas and two electrodes across which a fairly high potential is applied. The small ionization current which flows when x-rays enter the chamber produces a small voltage across a resistor in series with the electrodes and this voltage is amplified and used to deflect an indicating meter.

It will be clear from Fig. 6 that the angle between the incident ray and the reflected ray will be the supplement of twice the Bragg angle θ, and if the relative positions of the collimator, specimen holder and ionization chamber are fixed, the only permissible adjustment being a rotation of the specimen, then it will only be possible to investigate atomic planes having that one particular Bragg angle of which there are seldom more than one. Commercial x-ray equipments are therefore usually equipped with five fixed positions into which the ionization chamber can be locked, corresponding to the Bragg angles of the five atomic planes most commonly used for diagnosis. These are shown in Fig. 7. There are many more planes than these, but these have been selected by virtue of their strong reflexion ratios and convenient geometrical location. The atomic planes are identified by their Miller indices 011, 023, etc., every atomic plane throughout the crystal having a different number.

Recalling Braggs' Equation it can be seen that for constant values of d and λ, inserting values of $n = 1, 2, 3, \ldots r$ will give different values of Bragg angle θ. The reflexions at these different angles are called the first order, second order, third order . . . r^{th} order reflexions respectively. Examples of second and third order reflexions are shown in the two outermost columns of Fig. 7. Consider, for example, the 010 plane at 0° to the Z axis. The first order reflexion occurs with a Bragg angle of 10° 26′, and the second order reflexion with a Bragg angle of 21° 14′. The second order reflexion is designated 020, this being double the normal Miller index for that plane. Similarly in the case of the 001 plane, the third order reflexion is designated by 003 which is three times the normal Miller index.

The physical layout of most x-ray units limits the Bragg angles which can be accommodated to those falling within

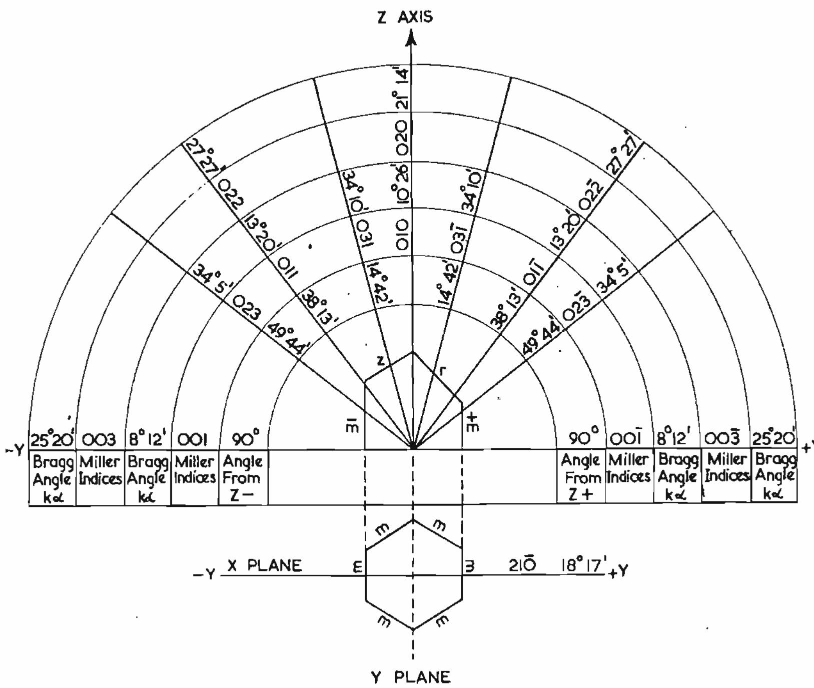


Fig. 7. Atomic planes in Quartz

the approximate range of 15° to 35°. For this reason it is often necessary to use the second and third order reflexions in preference to the first.

As an example of the type of calculation encountered in practice, let us assume that it is desired to check the angle of cut of a BT slice at −49° 10′. A convenient atomic plane is the 001 at − 38° 13′. This gives a difference angle between the plane of the slice and the atomic layer of 10° 57′. Using the second order or 022 reflexion with a

Bragg angle of 27° 27′ the beam will therefore have to be directed towards the slice at an angle of 38° 24′ of 16° 30′ depending upon which side of the slice faces the beam.

One point not yet mentioned is, that a check such as that just described, would give identical results, if the cut had been made into the wrong face at an angle of +49° 10′, the reflexion taking place this time from the 022 plane. A slight difference in reflexion ratio being the only indication of any discrepancy. It is therefore necessary first to ensure that the crystal is mounted in the correct relation to the cutting saw before it is any use checking the cutting angle in that way.

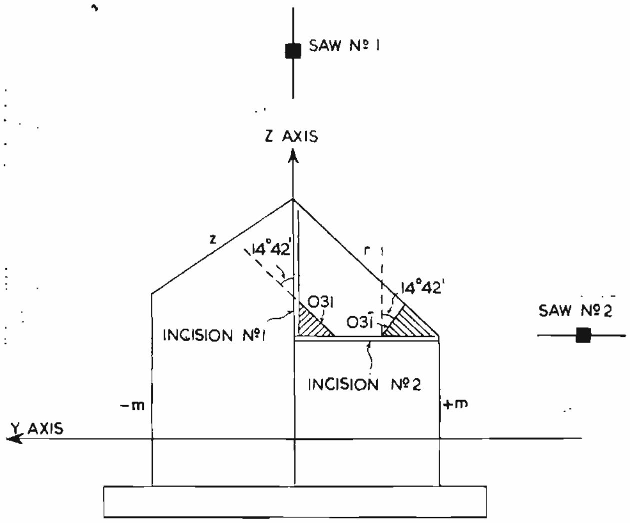


Fig. 8. Cutting the test piece

It is beyond the scope of this short article to describe the various optical means of determining the approximate positions of the Z axis and faces. Various devices are resorted to, to prepare the crystal ready for cutting. In one typical method the crystal is mounted with its Z axis horizontal and one X axis vertical. An incision is then made by means of a vertical saw along the plane formed by the horizontal Z and vertical X axes, i.e., the Y plane. This is shown in Fig. 8 as Incision No. 1. Incision No. 2 is then made into the side of the crystal along the plane formed by the horizontal Y and vertical X axes, i.e., the Z plane. Thus a small "test piece" of quartz is removed from the tip of the crystal. Faces are then ground upon it at angles of 14° 42′ to the vertical as shown, so as to expose the 031 and 03$\bar{1}$ planes which lie adjacent to a *z* face and an *r* face respectively. Since the relative strength of the reflected ray for the 031 face is 40 compared with 1.4 for the 031 face, these faces can be readily identified by comparing reflexion intensities on X-ray equipment having provision for the necessary Bragg angle of 34° 10′. Most Commercial units provide for a Bragg angle of 34° 5′ for the 023 and 02$\bar{3}$ planes and this is sufficiently close to 34° 10′ for this comparison check to be made. In this way the correct cutting face can be identified.

The "test-piece" provides much other valuable information, any divergence of the Y plane from the vertical being obtained by using the 020 reflexion from the 010 plane with a Bragg angle of 21° 14′, and any divergence of the Z plane from the vertical being similarly obtained by using the 003 and 00$\bar{3}$ reflexions from the 001 and 00$\bar{1}$ plants with a Bragg angle of 25° 20′. Also the difference in angle between the saw cut and the 001 and 00$\bar{1}$ planes is given, informing the machine setter how far the saw will have to be rotated to give the correct cutting angle.

One final application of x-rays of some importance is the Frequency Adjustment of Quartz Crystals.[5,6] It has been found that by irradiating a quartz crystal plate with x-rays it is possible to reduce its frequency slightly, due to a change taking place in the internal crystal matrix. It would appear that this method is only of value in a limited number of applications for the frequency change so obtained can be reversed if the crystal is heated above a certain temperature. This temperature which is usually quoted as 175°C is not encountered in normal operating conditions, but is sometimes exceeded in the various manufacturing processes, especially with the increasing demand for crystals mounted in sealed glass envelopes. Attempts on the part of the author to irradiate crystals after "bottling" have so far proved unsuccessful.

REFERENCES

[1] Cady, *Piezo Electricity*, McGraw Hill, New York, 1948.
[2] Voigt, W., *Lehrbuch Der Kristallphysik*, Teubner, Leipzig, 1928.
[3] Vigoureux, P., *Quartz Resonators and Oscillators*, H.M.S.O.
[4] Heising, R. A., *Quartz Crystals for Electrical Circuits*, Van Nostrand & Co. New York, 1946.
[5] Frondel, C., "Frequency Adjustment of Quartz Oscillator Plates by X-Rays," Reeves Sounds Laboratories Inc., New York, 1944.
[6] Symposium on Quartz Oscillator Plates, *American Mineralogist*, 30, 205-468, 1945

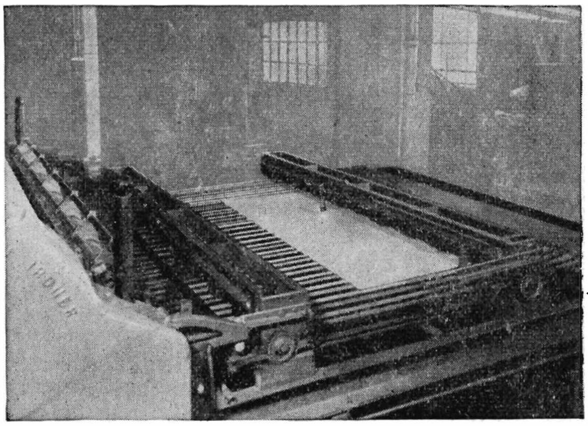
Photo-Electric Cell Control in Laundries *

A recent application of the photo-electric cell is in connexion with the folding of sheets in a large laundry.

The equipment, which is installed on the premises of James Bentley, Ltd., at Wilmington, Kent, was designed by Mr. K. Bentley, a director of the company, and is used to fold laundered sheets twice in the same direction. Each sheet is fed forward from an ironer on to a number of parallel moving webbing belts. When it has moved forward a few inches the leading edge of the sheet intercepts a beam of light falling on to an Osram photo-electric cell and thereby operates a row of pneumatic grippers arranged across the path of the sheet. These grippers hold the leading edge of the sheet and raise it slightly above the belts and as the remainder of the sheet is still moving forward a fold is created.

When the trailing edge of the sheet uncovers the light beam a relay mechanism releases the gripper fingers and the two edges of the sheet fall together and a perfect fold is completed.

The sheet then moves forward to a second photo-electric cell and gripper fingers and another fold is made in the same way.



The sheet folding machine

At this point the sheet is folded "long and narrow" and as the operator removes it from the folder she gives it the last transverse fold by hand.

* *Communication from G.E.C., Ltd.*

Winding Space Determination

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

IN the design of transformers and inductances for various purposes considerable time may be spent in calculating the space occupied by the required number of turns using various wire gauges. The charts given with this data sheet are intended to provide an accelerated means of making these calculations and at the same time provide a graphical comparison of the space occupied by different wire gauges and coverings.

Methods of Winding

RANDOM WINDING

Two methods of winding are provided for: that known as random winding, where the general arrangement of the turns is by layers but layer insulation is not inserted between every layer, with the result that small spaces left in any layer may be filled up with odd turns that drop down from later layers to fill the space. It is assumed that the winding follows a good layer arrangement as closely as possible so that throughout the winding operation the top of the winding is at all times, and at all points round the winding, parallel with the axis of winding and level. This method of winding is generally confined to the smaller wire gauges where insertion of layer insulation between every layer would result in a considerable percentage loss of winding cross sectional area. However, the precise gauge at which it may be deemed advisable to change from one method to the other depends upon the overall cross sectional area, the shape of the available space, the type of insulation employed as wire covering, and the voltage between turns or layers under working conditions.

LAYER WINDING

The other method of winding covered by these charts is known as layer winding, where some form of insulation is inserted between every layer of turns. In random winding the number of layers is usually fairly large and as the turns have a tendency to fall down to any spaces left by previous layers, a specification of the number of layers must be somewhat indefinite and the calculation simply becomes a division of the cross sectional area occupied by each turn into the total available cross sectional area. In the case of layer winding it becomes necessary to consider the exact number of layers employed, particularly where the number of layers is few. Often the theoretical number of layers, as derived by dividing the number of turns per layer into the total number of turns, is fractional or has an odd fraction of a layer, but this odd fraction will occupy as much depth in the winding as a full layer since the whole diameter of the wire has to be accommodated.

Wire Gauge and Insulation

The choice of wire gauge is usually dictated in some measure by considerations of efficiency, temperature rise due to resistance, or some similar factor which will depend upon the resistance of the wire, and in general will require that the largest possible diameter wire should be used. The choice of wire covering will depend upon the electric stress, between turns in the case of layer winding since layer insulation will take care of stress between layers, or between any turns that may fall adjacent one to another in random wiring; also upon mechanical force that may be applied to the wire during its working life. The winding may be subjected to mechanical strain of some sort directly or there may be some mechanical stress applied due to changes of temperature brought about by losses within the winding; the maximum operating temperature also exerts a controlling influence upon the suitable types of wire insulation. For the majority of light current duties enamel covered wire provides adequate insulation and mechanical strength, but for some special applications other types of covering given on these charts may become necessary. The presentation employed on the charts enables a direct comparison of the space occupied by alternative wire gauges with alternative forms of covering to be made quite readily.

The diameter of the wire is subject to certain variation during production and may vary as much as 10 per cent from its nominal diameter. This means that the cross sectional area of the wire may vary as much as 20 per cent from its nominal diameter. For this reason it is advisable in the design of production components to allow sufficient space to accommodate the nominal wire gauge specified when it is 10 per cent over size in diameter and on the same component the resistance of the winding should be of satisfactory value when the diameter of the wire is 10 per cent below its nominal value. If the design is based upon these conditions all practical variations in wire diameter for the nominal wire gauge employed will be satisfactory from both mechanical and electrical viewpoints.

TRANSFORMER DESIGN

In the case of transformer design the choice of wire gauge for the separate windings of the transformer will depend upon the relative numbers of turns in the respective windings and the desired distribution of the series losses in the transformer due to winding resistance. Assuming the more general requirement of minimum overall series loss, which is generally taken to be equal referred primary and secondary resistances, that is the resistance of the windings is in proportion to the square of the number of turns in each winding, the true minimum is given when each winding occupies exactly equal cross sectional area in the winding space. With some winding arrangements the length mean turn for the two windings will differ and if this equal division of area is employed the result will be that the referred resistance for each winding will not be exactly equal. However, the choice of wire gauge to give equal division of winding area will produce the true minimum of series losses since the greater mean turn length of one winding will mean that variation in relative sectional area per turn will result in correspondingly greater variation in the component of total series loss due to that winding. In the case of windings designed for Class B operation, bi-phase rectification or multi-ratio working, a cross sectional area distribution according to the theoretical ideal distribution of losses will give the true optimum working conditions rather than an arrangement that may more closely approximate the theoretical ideal distribution according to actual resistance values. The exception to this rule is where the internal winding insulation becomes an appreciable fraction of the total winding space, such as with extremely fine wire gauges or where it is deemed necessary for any reason to employ one of the heavier forms of covering. Under these conditions the ideal arrangement from the viewpoint of loss distribution is that in which the total cross sectional areas of copper in each winding conform to the specified loss distribution.

Where few turns of large gauge are required it often occurs that considerable space may be wasted due to the odd layer fraction. If further windings are to be placed on top of the odd layer fraction it may be the practice to fill up this lost space with insulation material in order to provide a level foundation as a base for the next winding. In these days when economy in size and weight is often of importance it is worth considering whether some alternative arrangement could not make it possible to utilize such lost space. This may have additional advantages, such as reducing leakage inductance or providing better cooling for the windings as a whole, since the thick wad of insulating material will also behave as a heat barrier preventing heat generated in one part of the windings from being conducted away for dissipation.

There is a variety of ways in which the problem of the odd layer fraction may be approached, and use of the charts given in this data sheet enable the best solution of the problem to be found more readily than would be possible by the use of protracted calculations. Sometimes the use of strip wire in place of the more normal circular section wire gauge will enable the space to be filled more economically, or sometimes the employment of two or more smaller diameter conductors wound in parallel will provide the necessary number of turns without producing an odd fractional layer and will utilize the theoretical winding area without introducing a practical wastage of area.

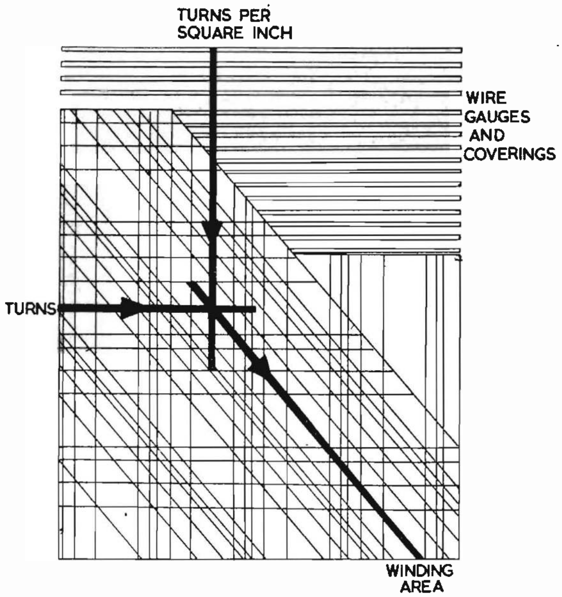


Fig. 1. Method of using Chart 1

An alternative method of utilising space left by odd fractions of layers is sometimes available in multi-winding transformers where some of the windings only require to occupy comparatively small cross sectional area. In the case of a mains transformer design it may be possible for a number of heater windings to occupy the same layer, or if the space required by the heater windings still leaves an odd layer fraction, a small winding such as might be required to feed a low current rating bias supply might be arranged to fill conveniently the remaining space.

In the case of layer winding design it is a good plan to tabulate the depth of winding taken up by various materials in the winding. This enables the space occupied by the conductor material to be checked from the viewpoint of its approximation to optimum distribution independently of the physical space occupied by the winding complete with its layer insulation. At the same time the complete tabulation will enable the designer who finds he has used up more than his available space to see immediately where economy in space can most readily be effected so as to produce a workable design.

Using the Charts

Fig. 1 illustrates the use of the chart intended for random winding. The total available winding area using the chosen bobbin and lamination size is first determined. Then, referring the number of turns along the horizontal reference lines from the left-hand side of the chart to intersect with the vertical reference corresponding to the turns per square inch given by the wire gauge and covering chosen, the point of intersection referred down the sloping reference lines gives the area occupied by this winding. This procedure is repeated for each winding of a transformer and due allowance made for insulation between windings to ensure that the required numbers of turns of wire gauges chosen will go satisfactorily into the available winding space.

Fig. 2 illustrates the use of the chart designed for layer winding. Referring the number of turns along the horizontal reference lines to intersect with the vertical reference corresponding to the chosen wire gauge, this point of intersection is referred along the sloping lines to intersect with the vertical reference corresponding to layer length. As shown in Fig. 2 this sloping reference is downwards from left to right. If, however, the vertical reference corresponding to the wire gauge is to the right of the vertical reference line corresponding to layer length, the direction of reference will be upwards from right to left along the same lines. If the point of intersection between this sloping reference and the layer length comes between the reference lines sloping in the opposite direction representing a number of layers then the reference line corresponding to the next highest integral number of layers should be used. The intersection between this sloping reference line and the original chosen vertical reference corresponding to wire gauge will indicate the depth of winding required by the wire on the scale to the horizontal reference lines at the right-hand side of the chart.

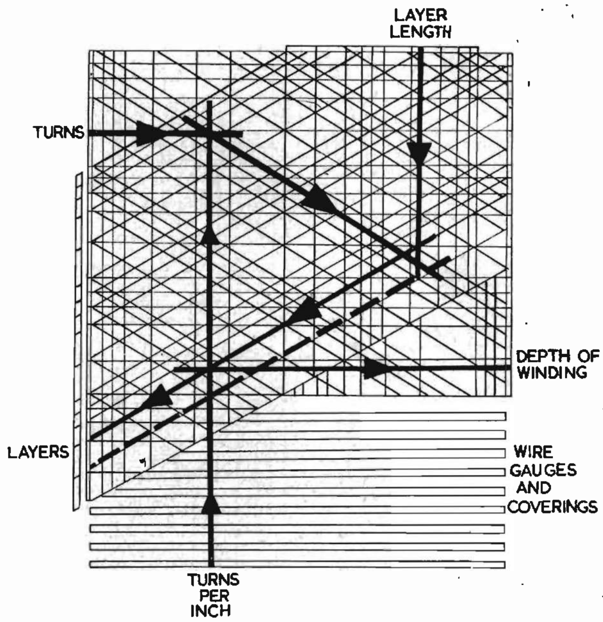


Fig. 2. Method of using Chart 2

Fractional Layers

Where a fractional number of layers is shown and it is desired to utilize the space left over by the layer fraction, the chart may be used in reverse to find the number of turns that can be accommodated by the integral number of layers before the fraction represented by the dotted line

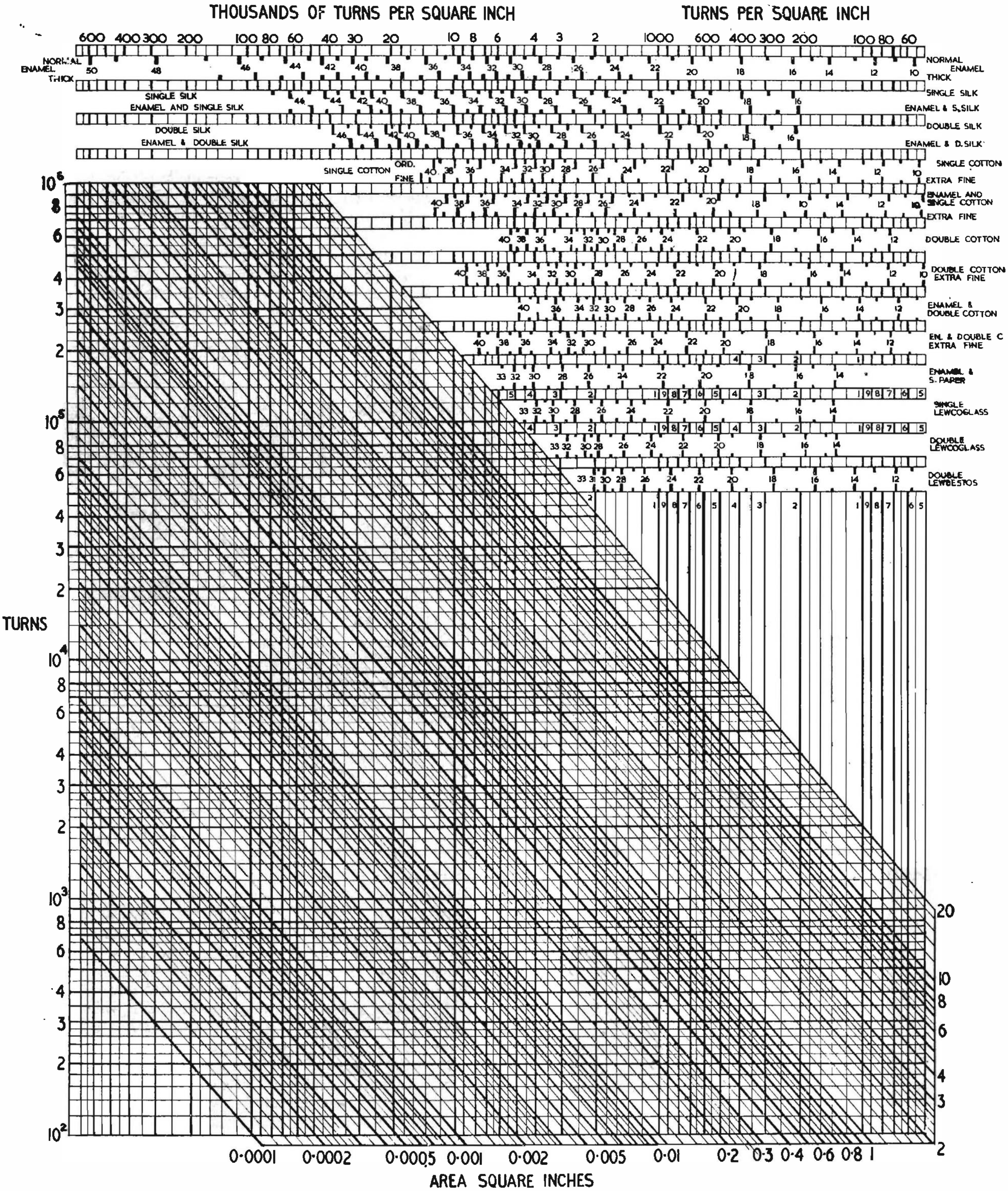


Chart 1. For random winding

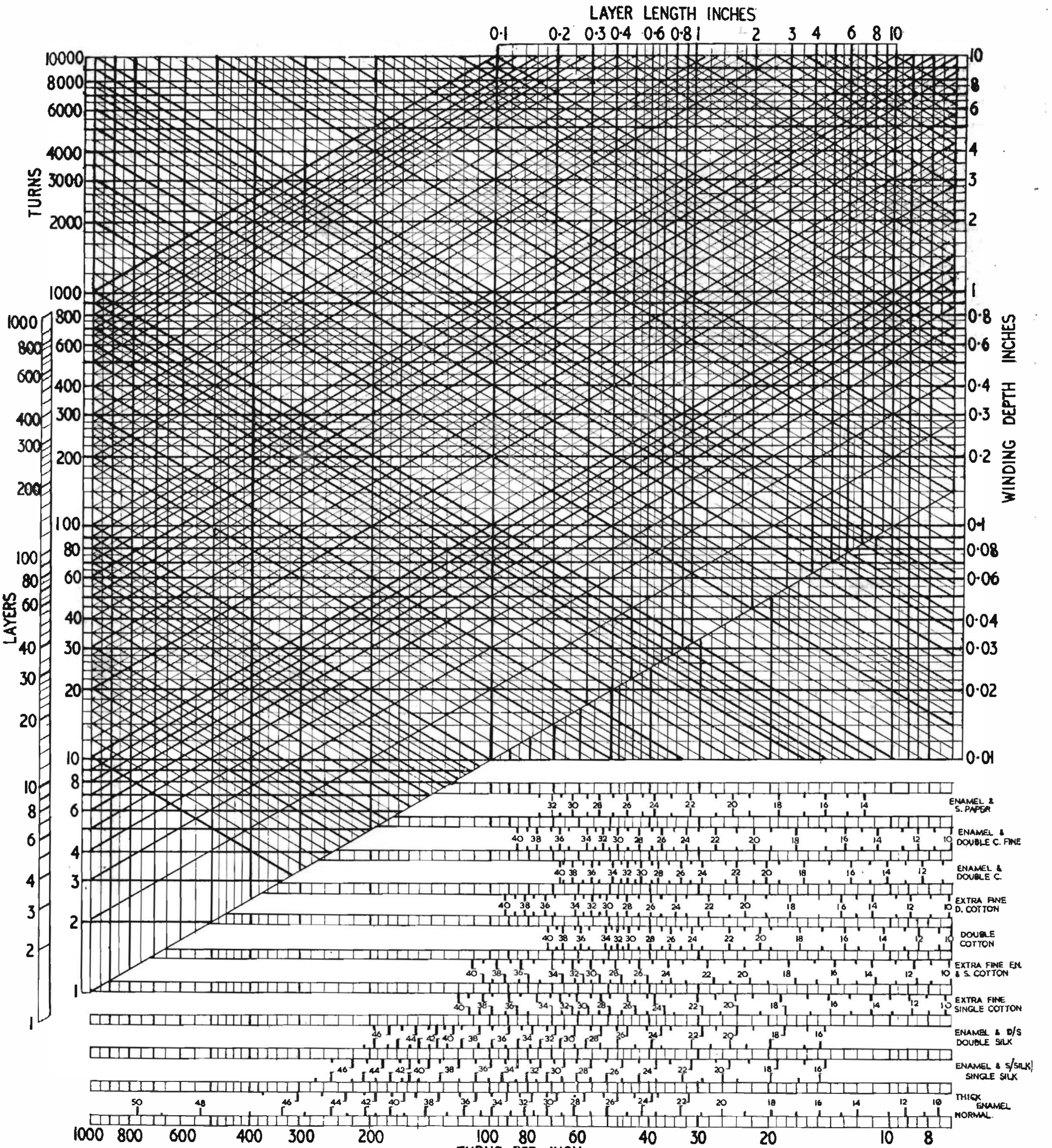


Chart 2. For layer winding

on Fig. 2 and this number can be subtracted from the total number of turns required. The remaining turns can be referred to the same wire gauge vertical reference and the point, where the sloping reference from this intersection intersects with the sloping reference line towards the bottom of the chart representing one layer, will give a point on the vertical reference lines whose scale is at the top of the chart indicating the length of layer occupied by this number of turns. The remaining layer length and the thickness occupied by this particular wire gauge indicates the space available for utilization.

EXAMPLE 1

An inter-valve transformer having a primary winding of 4,000 turns and a secondary winding of 12,000 turns is to be wound on a bobbin having a space 0.5in. wide by 0.2in. deep. This gives an area of 0.1 square inches. Allowing about 0.02 square inches for inter-winding insulation and top covering insulation this means that as a first approximation each winding should occupy a space of about 0.04 square inches. Reference to Chart 1 shows that for the 4,000 turns a No. 46 S.W.G. enamel covered wire will occupy 0.04 square inches allowing for the wire gauge being up to 10 per cent over size, while the next smaller gauge, No. 47 enamel covered, will occupy about 0.027 square inches. For the 12,000 turn winding No. 48 enamel covered wire will occupy about 0.045 square inches, while No. 49 will occupy 0.029 square inches. The choice of 46 for the 4,000 turns and 48 for the 12,000 turns will probably result in too high a number of rejects due to the bobbins being over full, so the alternative choice would appear to be between the use of 46 and 49, or 47 and 48. The former would result in a transformer in which the majority of the space is occupied by the 4,000 turns, while the latter will result in a transformer in which the majority of the space is occupied by the 12,000 turns. The choice here would be dictated by series loss distribution, the facility with which the finest gauge wire can be wound, or possibly the wire gauges in stock or available.

EXAMPLE 2

A two-ratio transformer is to be wound on a bobbin occupying a window space of $1\frac{1}{2}$in. by $\frac{1}{2}$in. This will leave a practical winding length of layer of $1\frac{3}{8}$in. and a useful depth of $\frac{3}{8}$in. or 0.375in. The turns required are a winding of 400 turns, one of 4,000 turns and a third winding of 40 turns. The transformer is intended for use in such a way that the 4,000 turns is always in use, while either the 40 or 400 turn winding may be the other one in use. Allowing that about 20 per cent of the available depth will be used for layer insulation, the remaining total depth for occupation by wire is 0.3in. Based upon the above statement of operational requirements the windings having 40 and 400 turns should each occupy 30 per cent of the available space or about 0.09in., while the winding having 4,000 turns should occupy about 40 per cent of the available space or about 0.12in. Using Chart 2, 400 turns of 28 gauge enamel covered wire will occupy five layers and a depth of 0.083in. The 4,000 turn winding will be sandwiched between the 400 and 40 turn windings from the viewpoint of maintaining low leakage inductance in each of the operational conditions, but to investigate the space required take next the 40 turn winding: using gauge 18 enamel covered wire $1\frac{1}{2}$ layers would be required. One layer would occupy just over 0.05in., while two layers will occupy over 0.1in. To utilize this space more effectively a better arrangement is to use three windings of 40 turns of 22 S.W.G. enamel covered wire and connect them all in parallel. Each winding will conveniently fill one layer and the total depth will be 0.093in. Alternatively two layers of strip laying about 15 turns per inch, or 0.067in. overall, by 22 turns per inch or 0.045in. overall, will fill the space. Assuming the covering of such strip is enamel and single cotton, comparison of the turns per inch figures for 17 gauge in the region of 15 turns per inch shows that without covering the spacing would be about 17 turns per inch or 0.059 in., allowing 4 mil covering. Thus the nominal strip dimensions would be about 0.059in. by 0.037in. Turning to the 4,000 turn winding, the most convenient possibility is the use of 40 S.W.G. enamel covered wire which will occupy 18 layers and take up a depth of about 0.11in. This information can conveniently be tabulated together with the requirements as to layer insulation. Allowing 3 mil insulation between layers of the 22 and 28 gauge windings and one mil insulation between layers of the 40 gauge winding, also four layers of 3 mil insulation between windings and on top as a covering, the total depth, as tabulated below, adds up to 0.364in., which is just within the specified limit of 0.375in., allowing a little for loss of space due to curvature of the wire in winding, and still leaving adequate margin for clearance at the top of the bobbin (included in the original estimate of 0.375in.).

400 turns, 28 S.W.G. En., 5 layers	0.083in.
4000 turns, 40 S.W.G. En., 18 layers	0.110in.
40 turns, 22 S.W.G. En., three separate windings each 1 layer, 3 layers	0.093in.
Layer insulation, 3 mil, 5 + 3 layers	0.024in.
Layer insulation, 1 mil, 18 layers	0.018in.
Winding insulation, between windings and top, three of 4 × 3 mil	0.036in.
Total space occupied:	0.364in.

College of Aeronautics Presentation and Open Day

The College of Aeronautics at Cranfield held its Presentation and Open Day recently. The diplomas on this occasion were presented by Vice-Admiral M. J. Mansergh. C.B., C.B.E., who is Fifth Sea Lord. The Principal, E. F. Relf, C.B.E., A.R.C.S., F.R.Ae.S., F.R.S., is leaving the College, and his place will be taken by Air Marshall Sir Victor Goddard, K.C.B., C.B.E., M.A., from September 1.

The College runs a two-year post-graduate course, in addition to short holiday courses of one or two weeks' duration. In the two years' course it is possible to specialize in aero-dynamics, aircraft design, aircraft propulsion, and aircraft economics and production. Next year a new subject for specialization, namely, aircraft electrical engineering and electronics, is being added. On completion of the two year course the students are awarded the Diploma of the College (D.C.Ae).

The two-year course is quite different and considerably more extensive than any obtainable elsewhere in the country. While the basic mathematics, aerodynamics, thermodynamics and structural theory must of course be paralleled in universities, the College goes further in the application of this basic knowledge to the actual design of airframes and propulsion units, and to research methods in the various fields. The College of Aeronautics also possesses its own Flight Department, which enables the students to follow their ground studies into the air and learn of the methods of flight experimentation, both as a check and confirmation of theory and design and as a means of research.

Research work continues to develop, and to date 47 research reports have been published. The staff are encouraged to undertake research, and much of the students' second year work is of this nature.

Application of Matrices to Four Terminal Network Problems

By H. P. Biggar†

In any four-terminal network with linear elements there is a certain relationship between the current and voltage at the input terminals and the current and voltage at the output terminals. If the currents and voltages are as shown in Fig. 1

Fig. 1. Linear four terminal network

one simultaneous equation relating them may be written :—

$$\left.\begin{aligned} v_1 &= a_{11}v_2 + a_{12}i_2 \\ i_1 &= a_{21}v_2 + a_{22}i_2 \end{aligned}\right\} \qquad \dots\dots\dots\dots\dots\dots (1)$$

where a_{11}, a_{12}, a_{21} and a_{22} are constants depending only on the system. In matrix notation this equation becomes (see derivation of eq. (15)) :—

$$\begin{Vmatrix} v_1 & o \\ i_1 & o \end{Vmatrix} = \begin{Vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{Vmatrix} \times \begin{Vmatrix} v_2 & o \\ i_2 & o \end{Vmatrix} \qquad \dots\dots (2)$$

where $\begin{Vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{Vmatrix}$ is defined as the "A" or transfer matrix of the network, and is written $\| A \|$. It will be seen that the suffixes $_{11}$, $_{12}$, etc., have a particular significance, e.g. $_{11}$ signifies 1st term of 1st line, $_{12}$ is 2nd term of 1st line, etc., etc.

Equation (2) is usually abbreviated thus :—

$$\begin{Vmatrix} v_1 \\ i_1 \end{Vmatrix} = \| A \| \cdot \begin{Vmatrix} v_2 \\ i_2 \end{Vmatrix} \qquad \dots\dots\dots\dots (3)$$

The other form of (3) is easily seen from inspection to be :—

$$\begin{Vmatrix} v_2 \\ i_2 \end{Vmatrix} = \| A \|^{-1} \cdot \begin{Vmatrix} v_1 \\ i_1 \end{Vmatrix} \qquad \dots\dots\dots\dots (4)$$

In addition to equations (3) and (4) there are four other possible forms of the fundamental simultaneous equation :—

$$\begin{Vmatrix} v_1 \\ v_2 \end{Vmatrix} = \| Z \| \cdot \begin{Vmatrix} i_1 \\ i_2 \end{Vmatrix} \qquad \dots\dots\dots\dots (5)$$

$$\begin{Vmatrix} i_1 \\ i_2 \end{Vmatrix} = \| Z \|^{-1} \cdot \begin{Vmatrix} v_1 \\ v_2 \end{Vmatrix} \qquad \dots\dots\dots\dots (6)$$

$\| Z \|^{-1}$ is usually written $\| Y \|$

$$\begin{Vmatrix} v_1 \\ i_2 \end{Vmatrix} = \| D \| \cdot \begin{Vmatrix} v_2 \\ i_1 \end{Vmatrix} \qquad \dots\dots\dots\dots (7)$$

$$\begin{Vmatrix} v_2 \\ i_1 \end{Vmatrix} = \| D \|^{-1} \cdot \begin{Vmatrix} v_1 \\ i_2 \end{Vmatrix} \qquad \dots\dots\dots\dots (8)$$

From these six equations it is a simple matter to draw up the conversion table shown in Fig. 2. This table is self-explanatory, and shows how to calculate any required matrix from the constants of a known matrix.

	$\|A\|$	$\|Z\|$	$\|Y\|$	$\|D\|$	CIRCUIT MATRIX
$\|A\|$	$\begin{Vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{Vmatrix}$	$\begin{Vmatrix} \frac{z_{11}}{z_{21}} & -\frac{\lvert Z\rvert}{z_{21}} \\ \frac{1}{z_{21}} & -\frac{z_{22}}{z_{21}} \end{Vmatrix}$	$\begin{Vmatrix} -\frac{y_{22}}{y_{21}} & \frac{1}{y_{21}} \\ -\frac{\lvert Y\rvert}{y_{21}} & \frac{y_{11}}{y_{21}} \end{Vmatrix}$	$\begin{Vmatrix} \frac{\lvert D\rvert}{d_{22}} & \frac{d_{12}}{d_{22}} \\ -\frac{d_{21}}{d_{22}} & \frac{1}{d_{22}} \end{Vmatrix}$	$\begin{Vmatrix} v_1 \\ i_1 \end{Vmatrix} = \|A\| \bullet \begin{Vmatrix} v_2 \\ i_2 \end{Vmatrix}$
$\|A\|^{-1}$	$\begin{Vmatrix} \frac{a_{22}}{\lvert A\rvert} & -\frac{a_{12}}{\lvert A\rvert} \\ -\frac{a_{21}}{\lvert A\rvert} & \frac{a_{11}}{\lvert A\rvert} \end{Vmatrix}$	$\begin{Vmatrix} \frac{z_{22}}{z_{12}} & -\frac{\lvert Z\rvert}{z_{12}} \\ \frac{1}{z_{12}} & -\frac{z_{11}}{z_{12}} \end{Vmatrix}$	$\begin{Vmatrix} -\frac{y_{11}}{y_{12}} & \frac{1}{y_{12}} \\ -\frac{\lvert Y\rvert}{y_{12}} & \frac{y_{22}}{y_{12}} \end{Vmatrix}$	$\begin{Vmatrix} \frac{1}{d_{11}} & -\frac{d_{12}}{d_{11}} \\ \frac{d_{21}}{d_{11}} & \frac{\lvert D\rvert}{d_{11}} \end{Vmatrix}$	$\begin{Vmatrix} v_2 \\ i_2 \end{Vmatrix} = \|A\|^{-1} \bullet \begin{Vmatrix} v_1 \\ i_1 \end{Vmatrix}$
$\|Z\|$	$\begin{Vmatrix} \frac{a_{11}}{a_{21}} & -\frac{\lvert A\rvert}{a_{21}} \\ \frac{1}{a_{21}} & -\frac{a_{22}}{a_{21}} \end{Vmatrix}$	$\begin{Vmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{Vmatrix}$	$\begin{Vmatrix} \frac{y_{22}}{\lvert Y\rvert} & -\frac{y_{12}}{\lvert Y\rvert} \\ -\frac{y_{21}}{\lvert Y\rvert} & \frac{y_{11}}{\lvert Y\rvert} \end{Vmatrix}$	$\begin{Vmatrix} -\frac{\lvert D\rvert}{d_{21}} & \frac{d_{11}}{d_{21}} \\ -\frac{d_{22}}{d_{21}} & \frac{1}{d_{21}} \end{Vmatrix}$	$\begin{Vmatrix} v_1 \\ v_2 \end{Vmatrix} = \|Z\| \bullet \begin{Vmatrix} i_1 \\ i_2 \end{Vmatrix}$
$\|Y\|$	$\begin{Vmatrix} \frac{a_{22}}{a_{12}} & -\frac{\lvert A\rvert}{a_{12}} \\ \frac{1}{a_{12}} & -\frac{a_{11}}{a_{12}} \end{Vmatrix}$	$\begin{Vmatrix} \frac{z_{22}}{\lvert Z\rvert} & -\frac{z_{12}}{\lvert Z\rvert} \\ -\frac{z_{21}}{\lvert Z\rvert} & \frac{z_{11}}{\lvert Z\rvert} \end{Vmatrix}$	$\begin{Vmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{Vmatrix}$	$\begin{Vmatrix} \frac{1}{d_{12}} & -\frac{d_{11}}{d_{12}} \\ \frac{d_{22}}{d_{12}} & -\frac{\lvert D\rvert}{d_{12}} \end{Vmatrix}$	$\begin{Vmatrix} i_1 \\ i_2 \end{Vmatrix} = \|Y\| \bullet \begin{Vmatrix} v_1 \\ v_2 \end{Vmatrix}$
$\|D\|$	$\begin{Vmatrix} \frac{\lvert A\rvert}{a_{22}} & \frac{a_{12}}{a_{22}} \\ -\frac{a_{21}}{a_{22}} & \frac{1}{a_{22}} \end{Vmatrix}$	$\begin{Vmatrix} \frac{z_{12}}{z_{22}} & \frac{\lvert Z\rvert}{z_{22}} \\ \frac{1}{z_{22}} & -\frac{z_{21}}{z_{22}} \end{Vmatrix}$	$\begin{Vmatrix} -\frac{y_{12}}{y_{11}} & \frac{1}{y_{11}} \\ \frac{\lvert Y\rvert}{y_{11}} & \frac{y_{21}}{y_{11}} \end{Vmatrix}$	$\begin{Vmatrix} d_{11} & d_{12} \\ d_{21} & d_{22} \end{Vmatrix}$	$\begin{Vmatrix} v_1 \\ i_2 \end{Vmatrix} = \|D\| \bullet \begin{Vmatrix} v_2 \\ i_1 \end{Vmatrix}$
$\|D\|^{-1}$	$\begin{Vmatrix} \frac{1}{a_{11}} & -\frac{a_{12}}{a_{11}} \\ \frac{a_{21}}{a_{11}} & \frac{\lvert A\rvert}{a_{11}} \end{Vmatrix}$	$\begin{Vmatrix} \frac{z_{21}}{z_{11}} & \frac{\lvert Z\rvert}{z_{11}} \\ \frac{1}{z_{11}} & -\frac{z_{12}}{z_{11}} \end{Vmatrix}$	$\begin{Vmatrix} -\frac{y_{21}}{y_{22}} & \frac{1}{y_{22}} \\ \frac{\lvert Y\rvert}{y_{22}} & \frac{y_{12}}{y_{22}} \end{Vmatrix}$	$\begin{Vmatrix} \frac{d_{22}}{\lvert D\rvert} & -\frac{d_{12}}{\lvert D\rvert} \\ -\frac{d_{21}}{\lvert D\rvert} & \frac{d_{11}}{\lvert D\rvert} \end{Vmatrix}$	$\begin{Vmatrix} v_2 \\ i_1 \end{Vmatrix} = \|D\|^{-1} \bullet \begin{Vmatrix} v_1 \\ i_2 \end{Vmatrix}$

NOTE: $|A|^* = 1$ for networks with no internal sources of e.m.f.

Fig. 2. Matrix conversion table

The application of these matrices to network problems is summarized in Fig. 3, which shows the fundamental matrix equation for any combination of twin linear networks. In order to make use of the relationships in this table it is necessary to establish rules for the multiplication and addition of matrices.

Consider two linear networks in cascade with the constants shown (Fig. 4).

From equation (1) the corresponding simultaneous equations for these networks are as follows :—

* | | *signifies the determinant, e.g.*
$|A| = a_{11}a_{22} - a_{12}a_{21}$, $|Z| = Z_{11}Z_{22} - Z_{12}Z_{21}$, *etc.*

† *B.B.C Engineering Division*

$$\left.\begin{aligned} v_1 &= a_{11}v_2 + a_{12}i_2 \\ i_1 &= a_{21}v_2 + a_{22}i_2 \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

$$\left.\begin{aligned} v_2 &= b_{11}v_3 + b_{12}i_3 \\ i_2 &= b_{21}v_3 + b_{22}i_3 \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots (10)$$

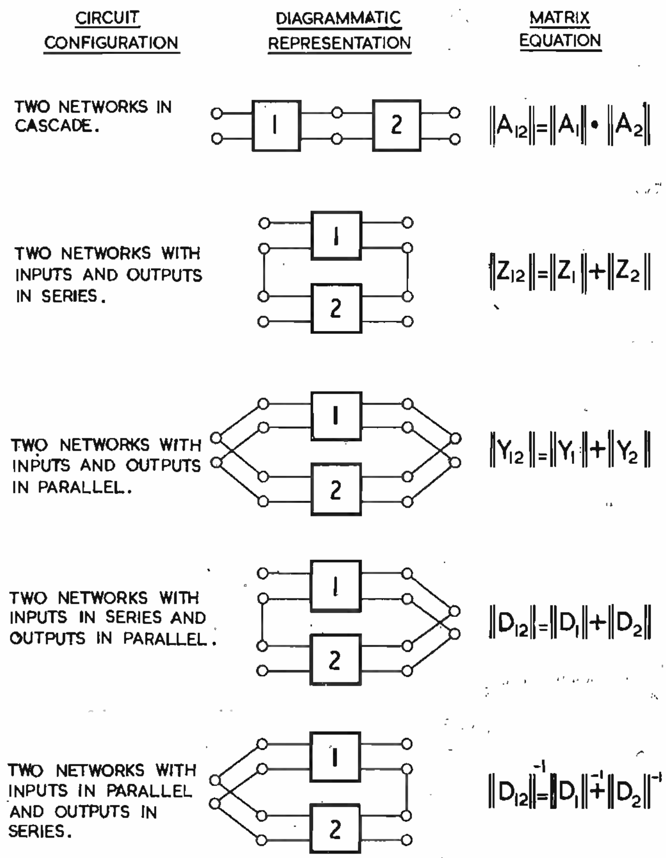


Fig. 3. Matrix equations relating to five combinations of twin four terminal networks

Eliminating $v_2 i_2$ from equations (9) and (10)

$$\left.\begin{aligned} v_1 &= (a_{11}b_{11} + a_{12}b_{21})v_3 + (a_{11}b_{12} + a_{12}b_{22})i_3 \\ i_1 &= (a_{21}b_{11} + a_{22}b_{21})v_3 + (a_{21}b_{12} + a_{22}b_{22})i_3 \end{aligned}\right\} \quad \ldots\ldots (11)$$

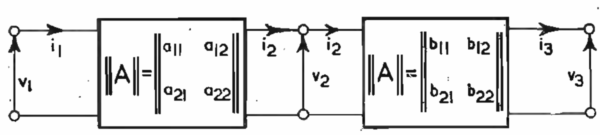


Fig. 4. Two linear networks in cascade

The matrix equations corresponding to (9) and (10) follow from equation (3) :—

$$\begin{Vmatrix} v_1 \\ i_1 \end{Vmatrix} = \begin{Vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{Vmatrix} \cdot \begin{Vmatrix} v_2 \\ i_2 \end{Vmatrix} \quad \ldots\ldots\ldots (12)$$

$$\begin{Vmatrix} v_2 \\ i_2 \end{Vmatrix} = \begin{Vmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{Vmatrix} \cdot \begin{Vmatrix} v_3 \\ i_3 \end{Vmatrix} \quad \ldots\ldots\ldots (13)$$

Eliminating $v_2 i_2$ from equations (12) and (13)

$$\begin{Vmatrix} v_1 \\ i_1 \end{Vmatrix} = \begin{Vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{Vmatrix} \cdot \begin{Vmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{Vmatrix} \cdot \begin{Vmatrix} v_3 \\ i_3 \end{Vmatrix} \quad .(14)$$

Comparing equations (11) and (14), the rule for multiplication of matrices is seen to be :—

$$\begin{Vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{Vmatrix} \cdot \begin{Vmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{Vmatrix} = \begin{Vmatrix} a_{11}b_{11} + a_{12}b_{21} & a_{11}b_{12} + a_{12}b_{22} \\ a_{21}b_{11} + a_{22}b_{21} & a_{21}b_{12} + a_{22}b_{22} \end{Vmatrix} \quad \ldots\ldots\ldots (15)$$

By means of this rule it is not difficult to see that equation (1) follows from expansion of the right-hand side of equation (2) at the beginning of this article. Similarly the rule for addition or subtraction of matrices may be shown to be :—

$$\begin{Vmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{Vmatrix} \pm \begin{Vmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{Vmatrix} = \begin{Vmatrix} a_{11} \pm b_{11} & a_{12} \pm b_{12} \\ a_{21} \pm b_{21} & a_{22} \pm b_{22} \end{Vmatrix} \quad \ldots\ldots\ldots\ldots (16)$$

By means of equations (15) and (16) and Figs. 2 and 3 it is possible to solve a large number of network problems.

As a particular example of the solution of network problems by Matrix Algebra it is proposed to derive a simple form of constant resistance equalizer from the lattice network shown with its composite equivalent in Fig. 5.

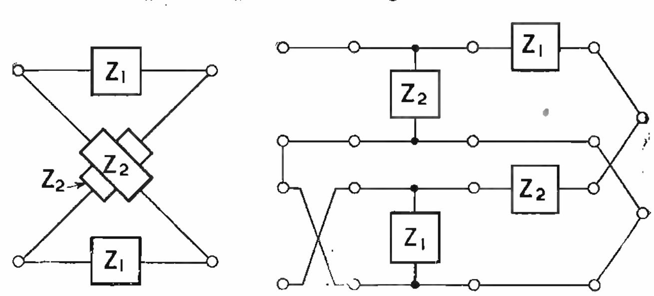
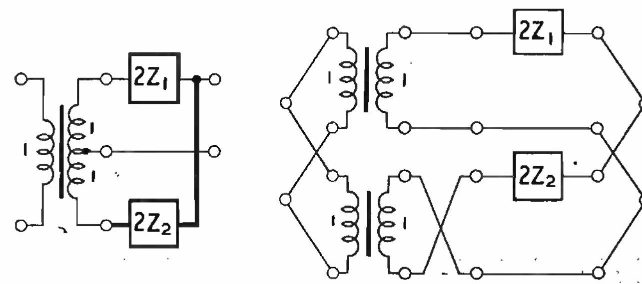


Fig. 5. Latice network and its equivalent circuit

When terminated with a resistance R the latter has a constant input resistance R at all frequencies provided $Z_1 Z_2 = R^2$.

The derived network and its composite equivalent are shown in Fig. 6.

Fig. 6. Equalizer having a balanced input and an unbalanced output and its equivalent circuit



In order to establish the equivalence of these networks it is only necessary to show that they have identical matrices. The " A " matrices of the component networks which together make up the equivalent network in each case are shown in the table in Fig. 7.

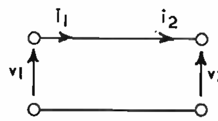
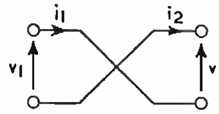
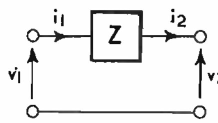
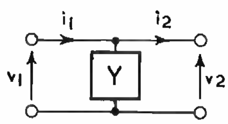
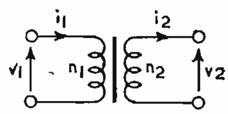
NETWORK	EQUATION	'A' MATRIX
	$v_1 = v_2$, $i_1 = i_2$	$\begin{Vmatrix} 1 & 0 \\ 0 & 1 \end{Vmatrix}$
	$v_1 = -v_2$, $i_1 = -i_2$	$\begin{Vmatrix} -1 & 0 \\ 0 & -1 \end{Vmatrix}$
	$v_1 = v_2 + Zi_2$, $i_1 = i_2$	$\begin{Vmatrix} 1 & Z \\ 0 & 1 \end{Vmatrix}$
	$v_1 = v_2$, $i_1 = \frac{v_2}{Y} + i_2$	$\begin{Vmatrix} 1 & 0 \\ \frac{1}{Y} & 1 \end{Vmatrix}$
	$v_1 = \frac{n_1}{n_2} v_2$, $i_1 = \frac{n_2}{n_1} i_2$	$\begin{Vmatrix} \frac{n_1}{n_2} & 0 \\ 0 & \frac{n_2}{n_1} \end{Vmatrix}$

Fig. 7. "A" matrices of five simple four terminal passive networks

The equivalent network of Fig. 5 consists of two subsidiary networks with their inputs in series and their outputs in parallel. For the upper network.

$$\| A_U \| = (\text{" } A \text{ " matrix of shunt element } Z_2) \times (\text{" } A \text{ " matrix of series element } Z_1)$$

in that order.

$$= \begin{Vmatrix} 1 & 0 \\ \frac{1}{Z_2} & 1 \end{Vmatrix} \cdot \begin{Vmatrix} 1 & Z_1 \\ 0 & 1 \end{Vmatrix}$$

$$= \begin{Vmatrix} 1 & Z_1 \\ \frac{1}{Z_2} & \frac{Z_1}{Z_2} + 1 \end{Vmatrix}$$

Converting this to the " D " matrix from Fig. 2 gives :—

$$\| D_U \| = \begin{Vmatrix} \frac{Z_2}{Z_1 + Z_2} & \frac{Z_1 Z_2}{Z_1 + Z_2} \\ -\frac{1}{Z_1 + Z_2} & \frac{Z_2}{Z_1 + Z_2} \end{Vmatrix} \quad \ldots\ldots (17)$$

Similarly for the lower network :—

$$\| D_L \| = \begin{Vmatrix} -\frac{Z_1}{Z_1 + Z_2} & \frac{Z_1 Z_2}{Z_1 + Z_2} \\ -\frac{1}{Z_1 + Z_2} & -\frac{Z_1}{Z_1 + Z_2} \end{Vmatrix} \quad \ldots\ldots (18)$$

adding equations (17) and (18) gives :—

$$\| D_U \| + \| D_L \| = \begin{Vmatrix} \frac{Z_2 - Z_1}{Z_1 + Z_2} & \frac{2Z_1 Z_2}{Z_1 + Z_2} \\ -\frac{2}{Z_1 + Z_2} & \frac{Z_2 - Z_1}{Z_1 + Z_2} \end{Vmatrix} \quad \ldots (19)$$

The equivalent network of Fig. 6 consists of two subsidiary networks with their inputs and outputs in parallel and, in this case, addition of the individual " Y " matrices gives the " Y " matrix of the system.

Multiplying the " A " matrices of the component networks, in the upper branch and converting the product to the " Y " matrix from Fig. 2 gives :—

$$\| Y_U \| = \begin{Vmatrix} \frac{1}{2Z_1} & -\frac{1}{2Z_1} \\ \frac{1}{2Z_1} & -\frac{1}{2Z_1} \end{Vmatrix} \quad \ldots\ldots\ldots (20)$$

similarly, for the lower network :—

$$\| Y_L \| = \begin{Vmatrix} \frac{1}{2Z_2} & \frac{1}{2Z_2} \\ -\frac{1}{2Z_2} & -\frac{1}{2Z_2} \end{Vmatrix} \quad \ldots\ldots\ldots (21)$$

adding equations (20) and (21) gives :—

$$\| Y_U \| + \| Y_L \| = \begin{Vmatrix} \frac{Z_1 + Z_2}{2Z_1 Z_2} & \frac{Z_1 - Z_2}{2Z_1 Z_2} \\ \frac{Z_2 - Z_1}{2Z_1 Z_2} & -\frac{Z_1 + Z_2}{2Z_1 Z_2} \end{Vmatrix} \quad \ldots (22)$$

Converting the right-hand side of equation (22) to the " D " matrix from Fig. 2 gives :—

$$\begin{Vmatrix} \frac{Z_2 - Z_1}{Z_1 + Z_2} & \frac{2Z_1 Z_2}{Z_1 + Z_2} \\ -\frac{2}{Z_1 + Z_2} & \frac{Z_2 - Z_1}{Z_1 + Z_2} \end{Vmatrix}$$

which is identical with equation (19). Hence the networks in Figs. 5 and 6 are exactly equivalent. The network of Fig. 6 may be useful as an equalizer where it terminates a balanced line and is itself connected to an unbalanced line amplifier or repeater.

Matrix algebra is explained at some length in Volume 2 of " Radio Engineering," by E. K. Sandeman, and this book is recommended for further study.

A Rapid Means of Calculating the Shunt Loss of an Output Transformer Fed from a Constant Current Source

By M. P. Johnson, A.M.I.E.E.*

RAPID calculation of the shunt loss caused by an output transformer working from a pentode valve can be made from the set of curves shown in Fig. 1. The loss is plotted for various values of the Q of the transformer core with the ratio $N = r_o/X_s$ as a variable, where r_o is the load resistance and X_s the shunt reactance of the transformer output winding.

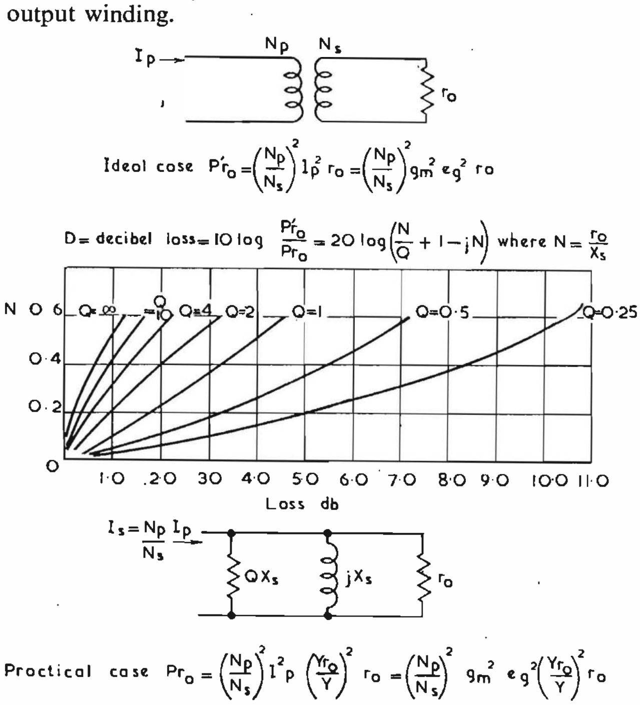


Fig. 1. Shunt loss of transformer

The derivation of the curves has been based on the assumption that a valve of high internal anode impedance can be treated as a source of constant current. A pentode valve working into an output load r_o is shown in Fig. 2(a) together with its equivalent circuit in Fig. 2(b).

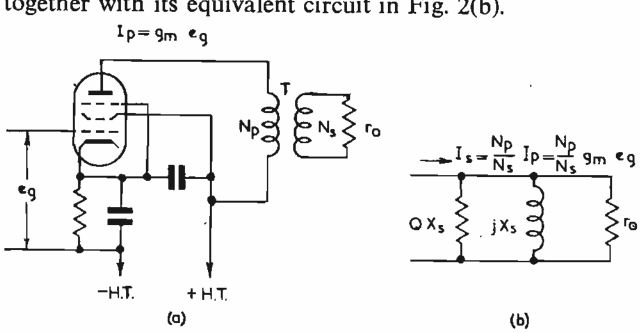


Fig. 2
(a) Pentode working into load r_o. (b) Equivalent circuit

In these figures:

e_g is the voltage applied to the control grid.
g_m is the valve mutual conductance.
N_p is the number of primary turns on the transformer T.
N_s is the number of secondary turns on the transformer T.
X_s is the shunt reactance of the secondary winding of T.
Q is the tangent of the phase angle of the stampings.

For stampings in common use, curves of Q (or phase angle) versus frequency are usually available. Q may be determined by taking the ratio of series reactance to effective series resistance of one of the windings. The copper resistance should be subtracted from the measured effective resistance before the ratio is taken.

If the transformer were ideal its shunt elements would be infinite and the power in the load would be:

$$Pr_o = (N_p)/(N_s)^2\, g_m^2 e_g^2 r_o$$

In the practical case the power in the load is:

$$P'r_o = (N_p/N_s)^2\, g_m^2 e_g^2\, (Yr_o/Y)^2 r_o$$

where Yr_o is the admittance of r_o and Y is the admittance of the three shunt elements of Fig. 2(b).

Then

$$P'r_o/Pr_o = (N/Q + 1 - jN)^2$$

where $N = r_o/X_s$.

The decibel loss, D, due to the insertion of a practical rather than an ideal transformer is:

$$D = 10 \log P'r_o/Pr_o$$
$$= 20 \log (N/Q + 1 - jN)$$
$$= 20 \log N/\sin\phi$$

$$\text{where } \phi = \tan^{-1} \frac{1}{1/Q + 1/N}$$

As an example of the use of these curves, suppose that at frequency f, $r_o/X_s = 0.5$ and $Q = 2$. From the curves the loss due to the transformer would then be 2.6db. At frequency $2f$, $r_o/X_s = 0.25$ and assuming that $Q = 2$, the loss from the curves is then 1.25db. Thus between frequency f and $2f$ the gain of the output stage has risen approximately 1.3db.

Given the variation of r_o/X_s with frequency, and also the variation of Q with frequency, a rapid calculation can be made of the response of the transformer over the whole of the frequency range.

* *General Electric Co., Ltd.*

A Simple Phase Shifting Device

By G. N. Patchett, Ph.D., B.Sc., A.M.I.E.E., M.I.R.E. *

THERE are many cases in a laboratory where a phase shifting device is required. A phase shifting transformer may be used, either a three-phase or single-phase type. The former is not always convenient as a three-phase supply is often not available and the latter is expensive and does not appear to be commonly available. An alternative is the use of a resistance-capacitance circuit, but these circuits have the disadvantage that the phase angle can only be varied continuously over an angle somewhat less than 180°. Larger angles can be obtained by switching, but this is not always convenient. To overcome these disadvantages the author has used the following arrangement, the apparatus having the advantage of cheapness and continuous variation of phase over any angle.

The device makes use of the resolver type of magslip which consists essentially of a rotor coil and two stator coils wound at right angles to each other. The magslip is constructed so that when the rotor is connected to a suitable supply, the voltage induced in one stator winding is proportional to the sine of the angle of rotation of the rotor, and the voltage induced in the other coil is proportional to the cosine of the angle of rotation. There is also

* *Bradford Technical College.*

another winding on the rotor, wound at right angles to the first. This winding is normally short circuited so as to neutralize any quadrature flux. The magslip is connected as shown in Fig. 1, a resistance-capacitance circuit being connected across each stator winding. The output voltage is the sum of the voltage across one capacitor and one resistor. By making R = reactance of C, the phase shift

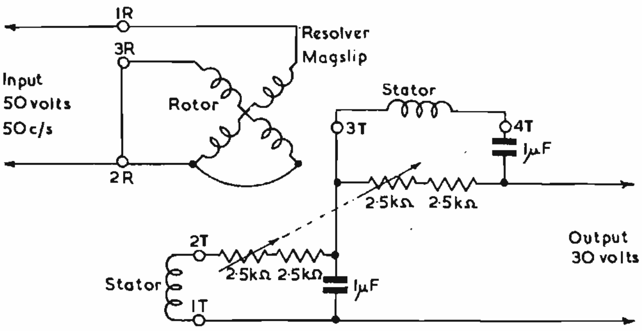


Fig. 1. Connexions of magslip

in each circuit is 45°. This means that the two voltages that are in series are 90° out of phase with each other. Since one voltage varies as the sine of the angle of rotation and the other as the cosine, the output voltage remains of constant value, but is of variable phase, a continuous variation of phase taking place, equal to the angle of rotation of the rotor. The only adjustment that has to be made is to make R = reactance of C. This will, of course, depend on frequency, but the adjustment is easily made if the resistors are ganged together so that they are always equal, the resistors then being adjusted so that the output voltage remains constant as the rotor is turned. This adjustment is much easier than the two adjustments required for a phase shifting transformer of the single phase type.

With the values shown the arrangement is only suitable for feeding a relatively high impedance circuit, such as the grid circuit of a valve. Although it is not intended as a precision instrument, the accuracy is about 1° with a load of 500,000 ohms. The absolute accuracy decreases to about 3° with a load of 125,000 ohms, but the change of angle still remains accurate to about 1°. The waveform is not a perfect sine wave, but is good enough for most purposes (containing about 3 per cent 3rd harmonic). The setting of R is not very critical and a change of frequency of 8 per cent causes a maximum error of 3° if R is not adjusted, but this may be reduced to 1° by adjustment of R, at the new frequency.

The apparatus has been found most useful as it gives a direct reading of phase over any angle required. The cost is quite small as this type of magslip is readily available from ex-Government stores.

A Process Timer

G. S. Errington

THE timer described gives reliable results from a small number of components.

Advantages arising from the circuit used are:—

(1) There is no resetting betweeen intervals. A simple make-one push button or external contact initiates the timed interval.

(2) The initiation does not depend on discharging a capacitor, with its problems of high surge current and residual charge.

(3) By the action of the barretter and the circuit, timed intervals do not vary widely with mains voltage variations.

(4) By the use of large grid voltages, a rapid change of grid potential and hence of plate current occurs at the end-point, giving sharp relay action.

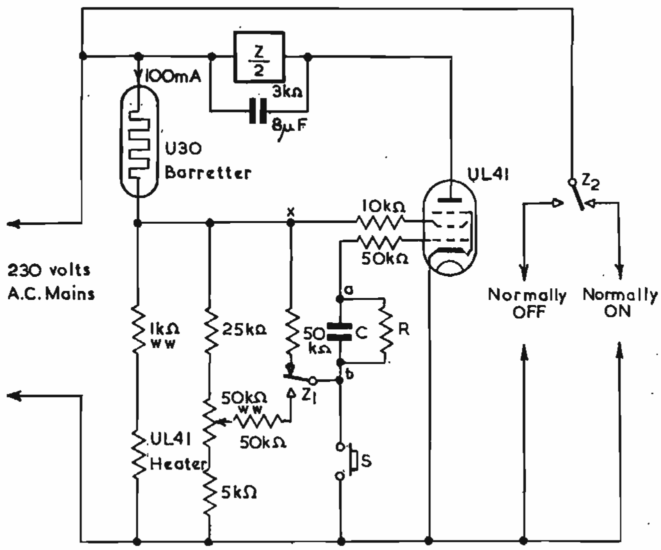
(5) Because of the absence of a power transformer the completed timer is light and can easily be adapted to D.C. mains. The barretter is less robust than a transformer and requires adequate ventilation but for many uses, e.g., photographic printing, this is not a disadvantage.

(6) During warm-up the normally ON outlet is OFF. In practice this is not a disadvantage and in fact, indicates when the timer is functioning.

In operation, plate current of the UL41 holds the relay in its anode circuit closed. Contacts Z_1 on this relay complete the circuit, cathode, grid, CR, to a point x 145 volts R.M.S. above cathode. By grid to cathode rectification, C, becomes charged to some 140 volts, with point a negative with respect to b.

If S is now pressed momentarily, b is brought to cathode potential and the grid is made 140 volts negative. Anode current is cut off and the relay opens. By contacts Z_1, point b is now connected to an adjustable alternating voltage less than the previous value. C discharges via R, and at a time determined by the setting of the 50kΩ control, the UL41 passes anode current and the relay closes. A shaded pole relay would be desirable, but the more readily available BPO 3000 type was used and worked reliably with an 8μF 450 volt electrolytic capacitor across it.

As shown, the circuit is limited to intervals greater than, say, one second, because the push-button must be released before the end of the timed interval. With the values shown, the maximum interval is about twice the CR product, i.e., with a capacitor of 2μF and a resistor of 5 megohms, a maximum interval of about 20 seconds is



Note. Contacts Z_1 make before break

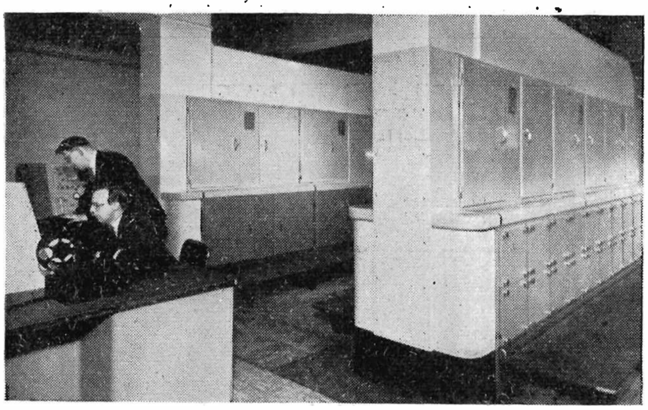
Fig. 1. Circuit of process timer

obtainable. At the end of such a 20 second interval, the grid voltage is changing by almost 2 volts/second, and the anode current by some 2.5mA/second, thus giving precise relay action. For shorter intervals, the rate of change of current is obviously greater being over 7mA/second at the end of 10 seconds. Centre scale on the 0-20 second range is at about 7 seconds.

Using an interval of 15 seconds and timing to ±0.2sec. no change could be detected when the mains were altered by 10 per cent. To give accurate repetition, 3-5 seconds must elapse between intervals, so that the capacitor can become fully charged.

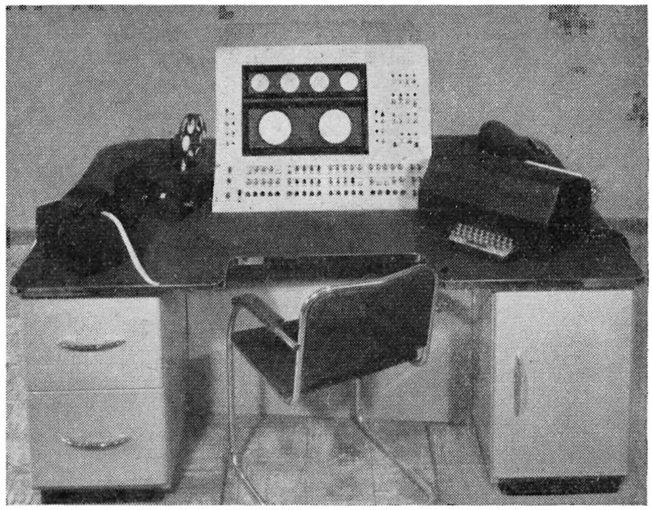
The Manchester University Automatic Digital Computor

AN Inaugural Conference of the Manchester University Digital Computor was held at the Manchester University between July 9 and 12. This computor was engineered by Messrs. Ferranti, Ltd., from designs which originated in the Electrotechnics Department of the University of Manchester. It was built on behalf of the Ministry of Supply, and is housed in a building provided by the Royal Society. It is the latest of a series of machines that have been built in England, in Europe and in America, and, in certain respects, it is believed to be the most versatile machine so far constructed. It is also probably the first machine of this type to be designed for production. The construction of this machine has taken about 18 months and Messrs. Ferranti, Ltd., expect to complete a second machine before the end of the year. They have started work on a third and propose to manufacture a whole series of computors.



A general view of the Computor.

The general construction of the computor can be seen from the two photographs. It is built in two bays, each 16ft long, 8ft high and 4ft wide. The electronic equipment is housed in large massively built racks and the components are wired in a manner that ensures easy accessibility. The whole of the electronic circuits are totally enclosed and are cooled by a forced draft of filtered air. It contains 3,500 valves, 12 cathode-ray tube stores and a magnetic drum capable of storing 16,000 twelve digit numbers. The cathode-ray tube stores are the invention of Professor Williams and Dr. Kilburn, both of Manchester University. In addition it includes 2,500 capacitors, about 15,000 resistors, 100,000 soldered joints and some six miles of wire. The total power consumption is 27kW. Reliability is one of the essential features of a machine of this type and, to this end, the valves are aged before being put into the computor and all the components have been carefully chosen and are considerably underrun. It is normally possible to locate any fault that has



The control desk of the computor.

developed by making the machine go through a standard test routine but, to assist in the location of any faults, test points are available on each chassis.

Problems can be put into the machine via teleprinter tape at the rate of 200 decimal digits per second and the machine prints its results on a standard teleprinter. In order to carry out a complicated computation it is of course necessary for the operator to supply the appropriate instruction to the machine and, in this respect, considerable skill is required on the part of the operator. It is estimated that an ordinary mathematician should be able to operate the machine effectively after about two weeks experience. Once the instructions have been supplied to the computor it will, however, decide the next step in a computation in the light of the results already achieved. Some idea of the speed with which this present machine can carry out computations can be gathered from the fact that it will add together two 12 digit decimal numbers in a total time of 1.2 milliseconds and it will multiply together two numbers of the same length in about 3 milliseconds.

It is certain that the introduction of high speed computing machines of this type will have a profound effect upon scientific work of all kinds and may even have an effect on commercial accounting. The following are some of the uses that immediately come to mind:—

Pure Mathematics—for the theory of numbers.

Astronomy—calculations concerning the structure of stars, of the orbits of comets, and the preparation of astronomical tables.

Physics—calculations of nuclear and atomic structure and the theory of plutonium piles.

X-ray Crystallography—the calculation of the shape and structure of molecules from the pattern which is produced on a photographic plate surrounding a crystal through which a beam of X-rays is passing. These computations, which are very laborious if done by ordinary methods, are of importance for example in rubber and plastic research, and to the chemist who is trying to synthesize complicated compounds such as penicillin.

Engineering—the analysis of complicated structures and problems associated with high speed and supersonic flight.

General Statistics—statistics of national importance, such as the census of production, which at the moment takes years to analyse.

Commerce—applications in this field are as yet in their infancy, but it may well be that they will be the most important of all. A single machine can do as much work as several hundred clerks, without the same risk of error.

A Simple Method of Indicating Makes and Breaks of a Circuit for Use in Portable Apparatus

By K. J. Brimley, B.Sc.*

DURING the development of an apparatus in this laboratory it was necessary to produce a permanent indication when contact was made momentarily between a pendulum and the stop. At the same time the circuit needed to be easily rearranged for setting up purposes so that it gave an indication on make which was automatically cancelled on break. The duration of the make in the first

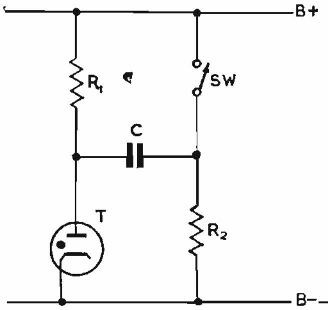


Fig. 1. Neon indicator and CR circuit

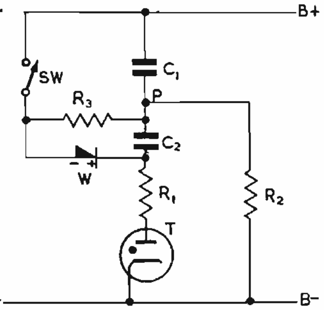
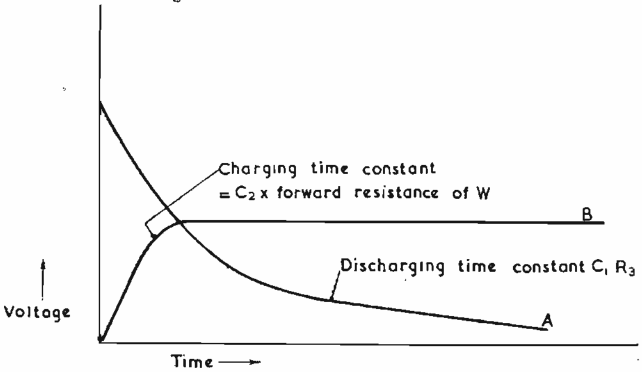


Fig. 2. Circuit for artificial increase of H.T. voltage

Fig. 3. Time constant of CR network



application might only be of the order of a very few milliseconds, making it difficult to use relays for sealing on. The particular apparatus had to be very light and compact and it was desirable that it should work from a small battery which would only have to be renewed at infrequent intervals.

The first part of the problem was easily solved using a neon indicator and a *CR* circuit as shown in Fig. 1. Capacitor *C*, normally charged to full H.T. voltage, was discharged through R_1 when *SW* was transiently closed. The H.T. voltage was normally insufficient to strike *T*, but when doubled by the discharge of *C* through R_1, it was more than sufficient, and the discharge once initiated, remained, since the voltage of *B* was greater than the burning potential of *T*.

The second part of the problem was more difficult without increasing *B* to greater than striking potential which in this case was undesirable. The circuit shown in Fig. 2 was, therefore, devised which enables the required effect to be obtained from the same voltage, using only small and easily obtained components, in addition to those used in Fig. 1.

* *Imperial Chemical Industries, Ltd., Nobel Division Research Department.*

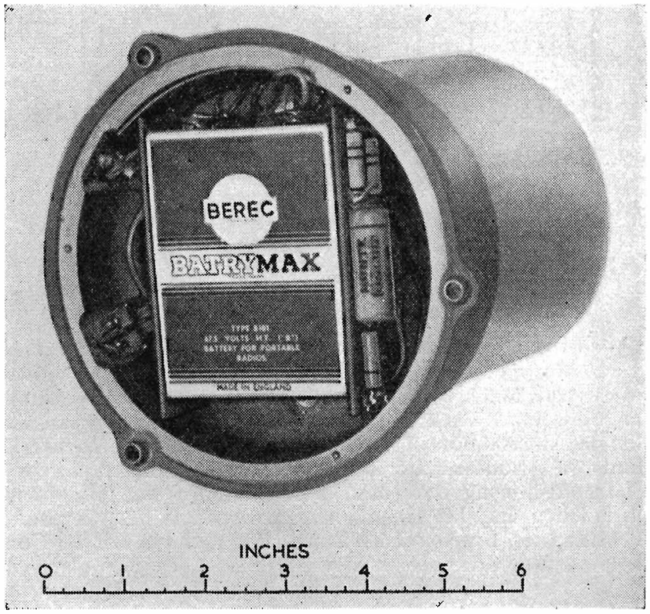


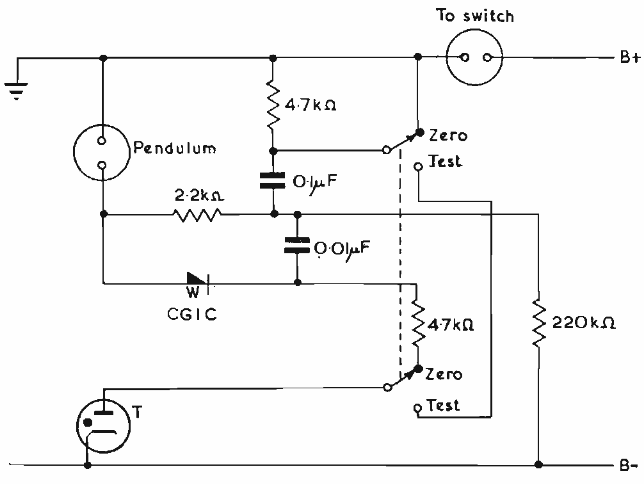
Fig. 4. The complete unit

C_1 is normally charged to full H.T. voltage when *SW* is open, while C_2 is normally discharged. Closing *SW* causes the charge on C_1 and C_2 to be shared. Thus if $C_1 \gg C_2$ almost full H.T. voltage will also be present temporarily across C_2. On closing *SW* the voltages across C_1 and C_2 are shown in curves *A* and *B* of Fig. 3. If the back resistance of *W* is high, a voltage not much less than *B* will be isolated on C_2 (assuming *T* does not strike) and this added to the positive potential of the battery at point *P* when C_1 is fully discharged will be more than enough to strike *T*. The discharge once initiated will continue through the forward path of *W* only for so long as *SW* is closed and will extinguish if *SW* is opened.

For *T* a Ferranti KD60 was ideal. It burns reliably with currents of 50μA up to 3mA, thus producing long life of *B*. Furthermore it will burn from the 67½ volts of a standard miniature H.T. battery, and it does not require excessive striking voltage. Of all samples tested, burning voltage was between 59 and 62.5 volts and striking voltages between 75 and 80 volts.

Fig. 4 shows a view of the apparatus indicating its compactness, while the final circuit used, including the switching from " set up " to " operate " is shown in Fig. 5.

Fig. 5. The final circuit including switching



The Telekinema at the Festival of Britain (South Bank) Exhibition

By V. E. Hughes*

A SMALL, ultra-modern theatre is one of the important features of the South Bank Exhibition of the Festival of Britain, and it was probably the first large-scale exhibit in full operation. In it the visitor to the exhibition can see the latest methods of large screen television, stereoscopic film projection and stereophonic sound reproduction.

The following is a brief description of the equipment installed in the Telekinema by Marconi's W. T. Co., Ltd., E.M.I., Ltd., Cinema Television, Ltd., and the B.T.H. Co., Ltd.

Television Camera and Control Equipment

Each programme at the Telekinema starts with a television interview. A notability is met in the foyer by an interviewer and, after being introduced to the audience via the television camera and large screen, is conducted on a tour of the control room when all the equipment is shown and explained. It is during this tour that the seated audience see all the equipment and learn its functions. The whole of this interview-tour is conducted to the screen by one Marconi camera.

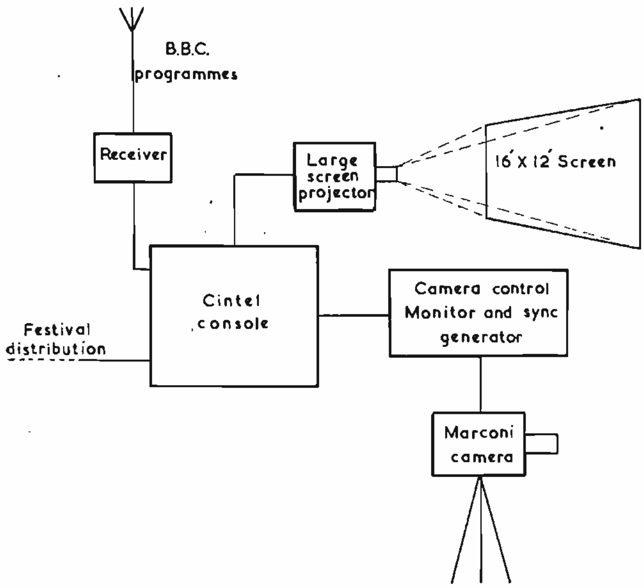


Fig. 1. Vision distribution

The picture passes from the camera tube to the Marconi camera-control, monitor, and synchronizing generator console and is then fed to the Cinema Television control console.

Large Screen Equipment

Two other sources of input are also fed to the control console, the normal B.B.C. vision programme (received on an ordinary domestic television receiver) and the line from the central control room of the South Bank in which the Rediffusion equipment is installed. Thus the Telekinema audiences can view pictures picked up by mobile cameras in the grounds of the Exhibition.

From the Cintel console the signal goes to the large screen projector and thence to the screen. A block schematic diagram of the vision equipment is shown in Fig. 1.

The console and projector are the main units of the Cintel installation. At the console the picture signals are received, corrected, and amplified before being passed to the projector. A 10in. aluminized tube provides a means of monitoring the outgoing picture at the console. Various types of input signals are accommodated through an interchangeable vision and sound coupling unit. Other units contained in this console are line and frame scan generators, focus modulator, video standby amplifier, tube projector, inter-communication facilities, programme sound coupling with fader and monitor loudspeaker.

The projector, which is remotely controlled, is completely enclosed in sheet metal to exclude dust and prevent external emission of X-rays. Between 40ft and 50ft is considered the ideal "throw" from projector to screen.

Sound from the same three sources is also passed via the Cintel console into the theatre system. In this case it is received from the B.B.C. vision programme, Rediffusion, and a Marconi BD.515 portable outside broadcasting box used to take the sound of the interview programme being televised in the foyer and control room.

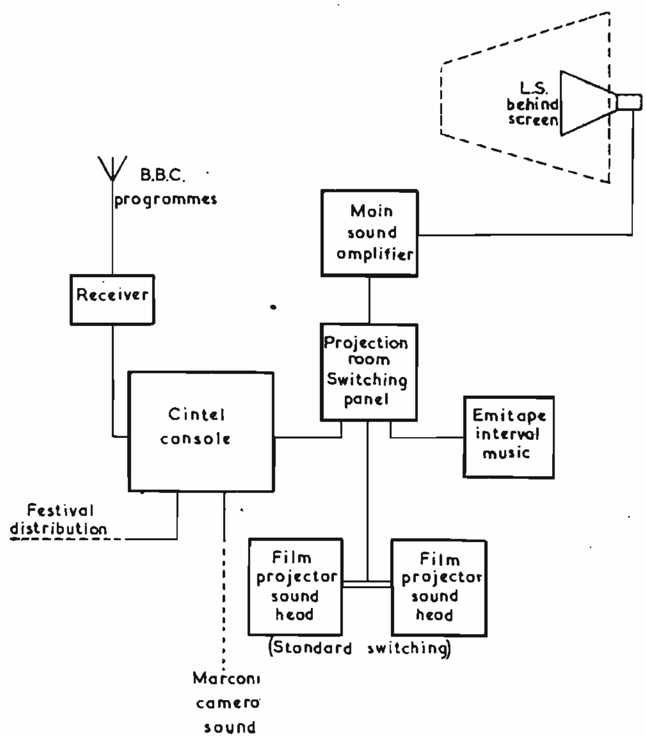


Fig. 2. Sound distribution

Sound from the Cintel console goes to the projection room switching panel as does that from the film projector sound heads and the Emitape interval music. From this switching panel it goes through a main sound amplifier to the theatre's loudspeaker system.

Other sound and vision inputs, in addition to those already mentioned, can be switched through to the theatre from selector panels in the control room having single outputs to the projector (for vision) and the B.T.H. main amplifier (for sound). The arrangement of the sound distribution equipment is shown in block schematic form in Fig. 2.

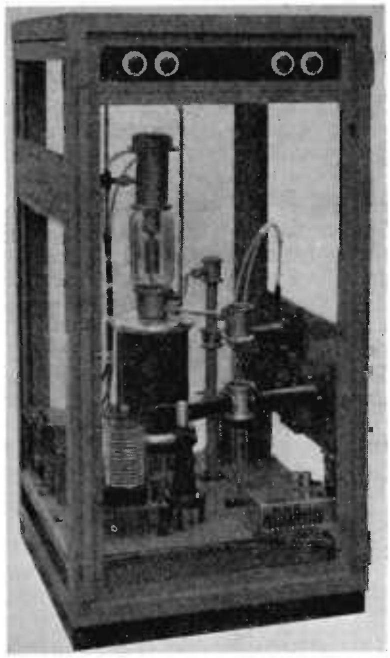
* *Marconi's Wireless Telegraph Co., Ltd.*

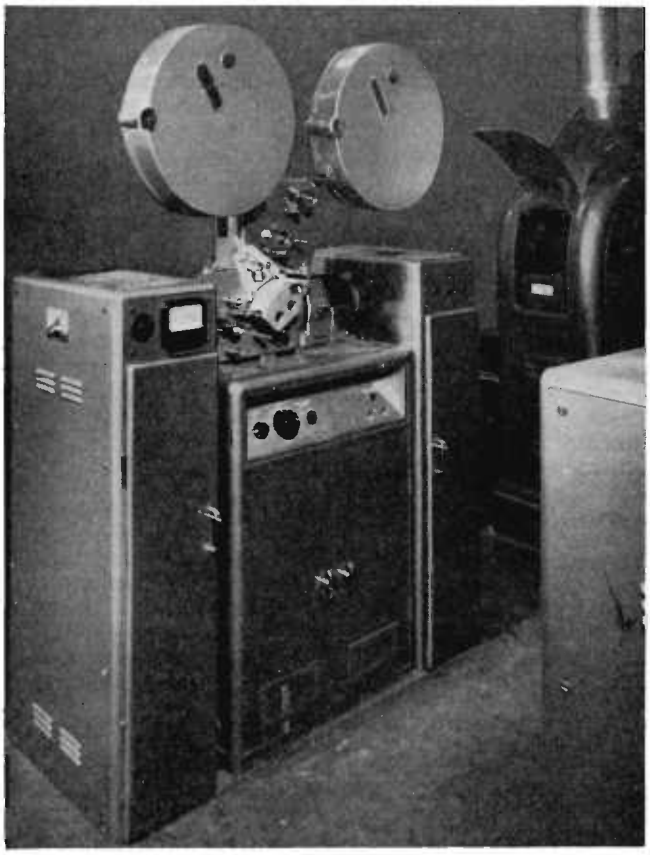
The Marconi Image Orthicon Television Camera and Control Desk.

(Above). The control on the Cinema-Television control console.

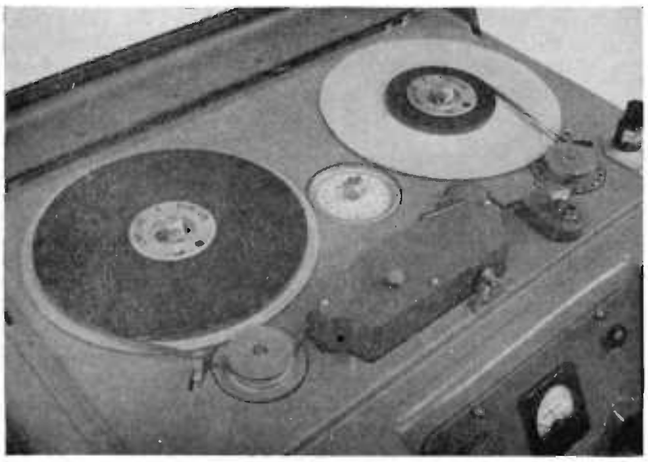
(Right). The high-tension unit which supplies 50 kV to the projector.

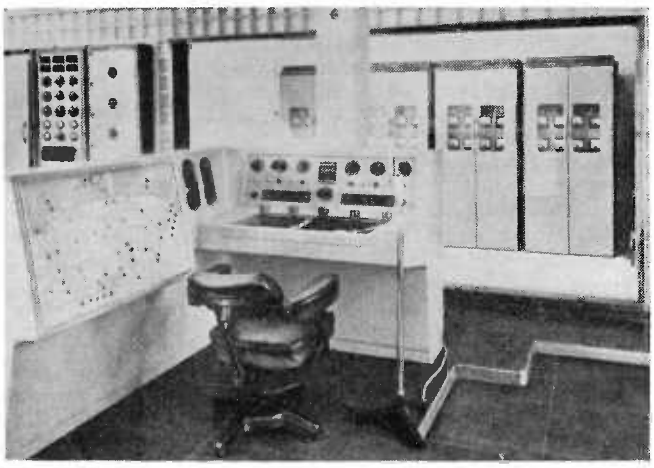
(Below). The Rediffusion control console in the Central Control Room.





(Above). One of the two sets of H.M.V. sterophonic sound equipment.
(Below) The E.M.I. tape recorder.





Stereoscopic Films

Stereoscopic pictures are projected on to the screen by two B.T.H. film projectors. To achieve a three-dimensional effect, two simultaneous images are projected which are accurately synchronized, but which are both of different polarity.

In order to interpret the three-dimensional effect, the human eye must have aid to appreciate the difference in polarity between the two pictures. This is achieved by the use of polarized spectacles.

Magnetic Recording and Reproducing

RECORDER SYSTEM

This equipment enables the simultaneous recording of four magnetic tracks side-by-side on 35mm perforated film, running at the normal film speed of 18in./second. This multi-track recording is necessary for the production of panoramic and stereophonic sound, and it is synchronized with the stereoscopic film projectors.

The recordings are made by energizing four individual record-heads from four recording amplifiers, operating with common bias and erase oscillators.

The recording amplifiers are essentially constant current generators, except at the higher frequencies, where pre-emphasis is employed. This corrects for inherent tape and head losses and ensures that the tape, when reproduced through the 4-channel replay system, will have an overall frequency characteristic within $\pm$2db from 50c/s to 15,000c/s.

The recorders are fed from balanced 600 ohm lines at a level of 1mW (for zero level recording) a control panel being provided for checking the individual record currents.

Replay System

Four replay heads pick up the signals from the individual tracks (at a level of 250μV for a zero level recording) and feed four replay amplifiers and associated equalizers.

In view of the low level of signal and the nature of the equalizer circuit (which is in effect a bass boost circuit at 6db/octave from approximately 2,000c/s to 50c/s) special low noise valves and components are used in the replay to ensure better than 59db unweighted.

Each replay channel provides a balanced signal output into 600 ohms at a level of 1mW (for zero level recording) to feed subsequent amplifiers.

The replay equipment is duplicated (i.e., "A" and "B" equipments). This enables the "dubbing" of master recordings by replaying on one system, feeding the recording console, re-recording, and monitoring immediately on the second replay equipment.

This 4-channel stereophonic system has been provided by H.M.V. in conjunction with B.T.H. who supplied the amplifier and speaker system.

Interval Music Equipment

Interval music is provided from standard $\frac{1}{4}$in. tape reproducers running at 30in./second and having overall frequency responses within $\pm$2db from 30c/s to 12,000c/s with signal-to-noise ratio 56db for 2 per cent R.M.S. distortion.

Two machines are arranged with a common control panel, one as a "Main" and the other as a "Standby."

The equipment is fully independent of all the other projection room equipment and is so arranged by relays that in the event of failure of any of the other equipment, the interval music machines are able to supply programmes continuously.

ACKNOWLEDGMENTS

The Author wishes to thank Messrs. Marconi's W. T. Co., Ltd., E.M.I., Ltd., Cinema Television, Ltd., and the B.T.H. Co., Ltd., for their help in the preparation this article.

Sound Distribution and Crowd Control at the South Bank Exhibition

The Central Control Room

The primary functions of the central control room are crowd control, the broadcasting of music, time signals and general announcements.

Festival site control is centred on a large scale map placed to the left of the operator in the rediffusion room and in the Festival control room. When it is necessary to centre control on a specified point on the site, for the purpose of making an announcement or the broadcasting of music, the operator turns to the map. Measuring 2ft by 3ft and mounted in a sloping position, the map, covered with glass, has a series of push-buttons affixed against a diagrammatic background of the Festival site area. The operator selects the point or points to be covered with broadcast music or announcements and pushes the appropriate button for the particular site point. The buttons light up—coloured—showing that control is centred upon the specified points and that the point is receiving music or announcements.

Sound coverage throughout the Festival site is mostly on a low-level basis. The amplifying equipment includes four high powered amplifiers, giving a total of 6kW. each controlled by an automatic monitor. More than 1,200 loudspeakers have been set up throughout the 27 acre Festival site.

The network, with two distinct functions, has meant that the feeder system has had to be divided into two separate schemes. Feeders associated with entrances and exits are known as "A" scheme feeders, while the remaining feeders are referred to as "B." There are 24 "A" feeders covering 16 exits and eight entrances and 34 feeders for the "B" scheme.

Radiating from the control centre, the feeders run through three main underground duct routes. These routes also carry cables associated with other Festival management services, crowd-counting, light signals, fire alarms and clocks. All feeder switching is effected through relays. Primary switches are included in the control panels in the rediffusion control room and the Festival main control room.

Crowd Counting Equipment

This comprises sixteen 5-digit counters made up from automatic telephone equipment. These are capable of receiving impulses from eight groups of turnstiles and are arranged to count the number of operations of the turnstiles at eight entrances situated at remote parts of the Exhibition. The number of operations when the turnstiles are allowing people to enter the Exhibition are recorded on separate counters to the counters capable of recording persons leaving the exhibition. These are of the high speed type and similar in design to those used on totalisators. In addition there is a total counter for the "In" turnstiles and a total counter for the "Out" turnstiles and these are of the 6-digit type.

As a refinement and in order to eliminate the human element a 5-digit counter is installed, together with its relevant equipment, and this determines the difference between the "In" and "Out" totals, in other words computing the number of persons within the boundaries of the exhibition and displaying this at all times.

The display indicators are arranged so that the "In" totals for each entrance are beneath one another and at the bottom there is a grand total. The "Out" indicators are arranged similarly.

ACKNOWLEDGMENTS

Information on the crowd counting equipment was provided by Messrs. Rentrix, Ltd., and that on sound distribution equipment by Messrs. Control Rediffusion Services, Ltd.

NOTES FROM THE INDUSTRY

International Honours for E.D.A. Films.—Further international honours have come to the Electrical Development Association's series of educational films. One of the latest additions to this series, "Electricity and Light," part of which is in colour, has been selected for the next Venice Film Festival. This film, together with "Magnetism" and "Electrical Terms," has also been chosen for the Edinburgh International Festival.

From the outset of the film section of the Festival of Britain at the Science Museum, Kensington, the library has included the E.D.A. educational films "Electricity and Light" and "Putting Free Electrons to Work." A third film, "Magnetism," has now been selected for inclusion in the programmes.

Other international bookings of E.D.A. films are: International Scientific Film Association Congress at The Hague, Holland—"Magnetism" and "Electricity and Light"; Berlin Film Festival—"Electro-Chemistry" and "Fifty Acres," and Cannes Film Festival—"Magnetism."

Mullard Educational Film Strips.—Three more educational film strips entitled "The Story of Radio" and "The Cathode Ray Tube," Parts I and II, have been produced by Mullard's. These films are accompanied by booklets containing lecture notes.

"The Story of Radio" deals only with the subject of sound broadcasting, and is designed to trace the history and development of radio, while explaining in non-technical language how a broadcast programme is transmitted and reproduced. The filmstrip is intended for the age group of 11-16 years.

"The Cathode Ray Tube," Part I, covers the history, development and general principles of the tube, and Part II deals with construction and manufacture. These films are suitable for senior schools and technical colleges.

Full particulars are available from Unicorn Head Visual Aids Ltd., Broadway Chambers, 40 Broadway, London, S.W.1.

S.T. and C. and Western Electric.—Arrangements have been concluded such that the long association between Standard Telephones and Cables Limited and Western Electric Inc. in the whole field of telecommunications will be continued.

The City and Guilds of London Institute announces the adoption of a new scheme of courses and examinations in Instrument Maintenance (Subject No. 79), which has been drawn up by an authoritative Advisory Committee including representatives of industry, the Society of Instrument Technology, the Ministries of Supply, Fuel and Power, and Education, the Service Departments, major engineering professional institutions, and associations concerned with technical education.

The scheme is intended to meet the needs of mechanics and technicians concerned in the maintenance, repair and installation of the instruments used for process and production control in industrial plants and in H.M. Forces. Particular attention is given to the requirements of the chemical, iron and steel, and petroleum industries, to fuel economy, and the needs of the Services, but the structure of the scheme is such that it will be found to have wide application.

The course of part-time study is of five years duration, with an Intermediate Examination at the end of the third year, and a Final Examination at the end of the fifth year. There is provision for students holding an appropriate Ordinary National Certificate to enter the course at the beginning of the fourth year.

A pamphlet containing the regulations and syllabuses for the City and Guilds examinations will be available shortly, price 6d., from the City and Guilds of London Institute, Department of Technology, 31 Brechin Place, London, S.W.7. Further information about the scheme may be obtained from the same address.

V.H.F. for Southend Waterworks Co.—The Southend Waterworks Company has recently installed a V.H.F. radio system to provide communication between its headquarters and the company's vehicles.

This company maintains essential water supplies throughout an area of some 180 square miles in south-east Essex where the water mains traverse comparatively desolate areas, and where the soil is particularly corrosive in nature. Consequently burst water mains are not infrequent, and for prompt repairs a rapid means of communication is essential.

With this end in view, it was decided to install Ekco's V.H.F. F.M. communication equipment. At various points throughout the area, the company's officers have their cars equipped with a mobile transmitter/receiver, and the Head Office at Southend has a fixed transmitter/receiver installation, which has a selective calling facility for each unit. By using Head Office as a relay station, one unit can communicate with another.

The installation comprises a V.H.F. fixed station, which is a rack assembly, housing a transmitter, receiver and control unit, and a number of V.H.F. mobile units fitted to the company's vehicles.

The transmitter, which is crystal controlled, has a frequency of 85.325Mc/s, and a nominal power of 25 watts. The receiver, which is also crystal controlled, operates on a frequency of 71.825Mc/s. It is a double superhet having a sensitivity of the order of 1μV and is fitted with an automatic muting circuit which completely silences the set when a signal is not being received.

The equipment can be controlled from three positions. Normally control is from the rack assembly. The control unit at this position enables any one of the mobiles to be called without disturbing the others. It can also be used to establish two-way communication between mobiles. In this case the output from the receiver is arranged to modulate the transmitter so that any message received from a mobile is automatically re-radiated at full power on the main station transmitter frequency. With this system the maximum range of communication between mobile units is approximately twice the maximum range obtained between the fixed station and any one mobile unit. The output of the receiver is normally fed into a loudspeaker, but the first transmission from any mobile can be arranged to sound a warning bell.

English Television for Spain.—Spain is to have a comprehensive television system which will provide both studio and outside broadcasts for Spanish viewers. An order for over £139,000 worth of transmitting, studio, radiation and outside broadcasting equipment has been won by Marconi's Wireless Telegraph Co., Ltd., who were recently awarded the contract to supply television equipment for the forthcoming Canadian system, and an order for television equipment for the United Nations Organisation, to be installed at their new headquarters in New York.

Forthcoming Radio Show.—Referring to their advertisement on page 5 of the July, 1951 issue, the Radio Industry Council have asked us to point out that visits to installations and travel and hotel accommodation apply to visitors from abroad only. Overseas visitors are also asked to attend on the Special Invitation and Press Day, August 28, the Show is not open to the public and home buyers until August 29.

Change in Osram Valve Bases.—The General Electric Co., Ltd., is increasing the diameter of the bases of the following types of Osram valves from 30 millimetres to 34 millimetres: types X61M, W61, DH63, Z63, H63, L63, and W63. Some types have already been changed and others are being changed in the near future, but the increased size should be borne in mind in connexion with screening cans.

The manufacturers claim that new design will eliminate the trouble of bases becoming loose.

A Judgment Box.—In this article, on page 257 of the July issue, there appeared a mistake in one of the equations, owing to a printers' error. Line eleven in the first column should read

$$\sum_{i=1}^{n} I_i = \sum_{i=1}^{n} V_i G_i - V \sum_{i=1} G_i$$

BRITISH INSTRUMENT INDUSTRIES EXHIBITION

A Selection of New Equipment shown at Olympia, London, from July 4th — 14th, 1951.

Avimo Continuous Multi-Channel Cathode Ray Tube Camera

THIS camera has been designed for recording multiple traces of vibrations induced in various types of structures, or of variations in load in a wide range of mechanisms.

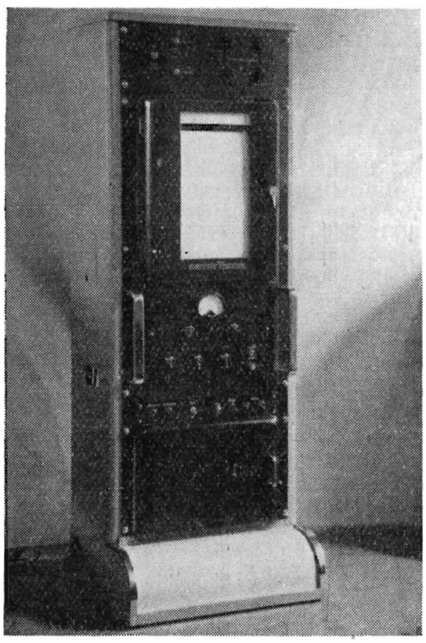
The camera and fifteen 1½in. (37mm) diameter cathode-ray tubes are contained in one unit. The tubes are disposed on either side of the camera, eight on one side and seven on the other, with their screens facing in the same direction as the twin lenses (3in., f/2.9); their axes are relatively disposed at an angle of 36°. Adjustable mirrors, arranged in batteries, reflect the traces along the axis of each lens. The combined images are thus focused on a vertical zero line, and the staggering of the tubes permits the accommodation of fifteen traces on the 60mm effective width of the 70mm film employed.

The film is motor driven (governed at 3,000 R.P.M.) via a six-speed gearbox. The capacity is 100ft of 70mm film. A meter records the length of unexposed film on the take-off spool.

Time marks are recorded by two integral lamps of the argon discharge type which, operated by an external circuit, record a small dot on the lower rebate of the film, and a thin line across the whole film, respectively.

Unit console construction is normally employed with a camera situated on top, when the camera is supplied with auxiliary electronic equipment, i.e., amplifiers, E.H.T. power pack, integral pulse generators, etc.

**Avimo Ltd.,
Taunton,
Somerset.**



Portable Radiation Thickness Gauge

AN interesting feature of this instrument is that it can be used in the form of a laboratory "hook-up" on continuous strip measurements by separating the top and bottom components. The radioactive source is contained in the lower portion and this can be detached and fixed to any suitable support on one side of a moving web. The upper portion which contains the ionization chamber can similarly be fixed opposite the source on the other side of the moving web. This does not, of course, make it into an industrial instrument suitable for permanent works installation, but it does provide the laboratory with means for carrying out observations on industrial processes and for establishing the proper situation and conditions for the installation of an industrial instrument.

**Baldwin Instrument Co., Ltd.,
Brooklands Works,
Dartford,
Kent.**

Cambridge High Speed Multipoint Recorder

(Illustrated bottom left)

THIS instrument is a development of the Cambridge Quick Acting Recording in which the continuously inking pen has been replaced by a mechanism for producing dotted records in differentiating colours of up to six phenomena on the same chart. The high response speed of the Cambridge recorder makes it possible to record one point on each of the six records in as little as 15 seconds.

The recorder is connected by means of a motor driven switch to each circuit in turn and the measuring system balanced by means of a differential electromagnetic clutch, forming the output element of an electronic error-operated servo. When balance is obtained, the mechanism causes a marker bar to drop, momentarily, on to an inked thread of appropriate colour and imprint a dot on the chart at a point corresponding to the magnitude of the phenomena being measured. As soon as each dot has been made, the rebalancing mechanism is made inoperative while the recorder is switched to the next circuit and a new colour thread brought into position. The circuit selecting mechanism also drives an indicator showing the colour and number of the record being made.

Multipoint recorders may be supplied for recording on either 2, 3, 4 or 6 channels and in all cases the time interval between consecutive measurements is 2.5 seconds.

The recorder chart is driven by a synchronous motor through a gearbox arranged so that chart speeds of 6, 3, 1½, ½, ¼ and ⅛ inch per minute may be selected at will.

**Cambridge Instrument Co., Ltd.,
13 Grosvenor Place,
London, S.W.1.**

Ekco Radiation Monitor

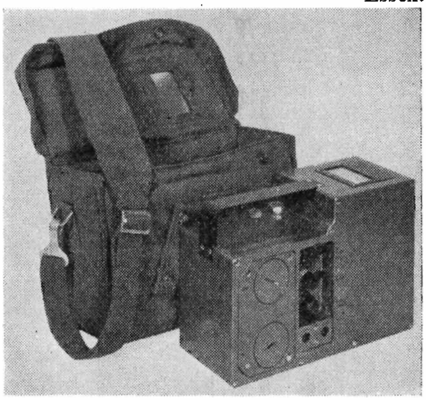
(Shown below)

A NEW hermetically sealed radiation monitor, type 1038A, has been designed by E. K. Cole, Ltd. It is supplied with a canvas carrying case to be used in the slung position.

The controls are available and the meter readable when the monitor is in its case. A novel feature of this instrument is the dial of the indicating instrument which rotates in sympathy with the range selection control knob.

It is robustly constructed and suitable for use under arduous conditions.

**E. K. Cole, Ltd.,
Ekco Works,
Southend-on-Sea,
Essex.**



Magnetic Sorting Bridge

(Illustrated top centre)

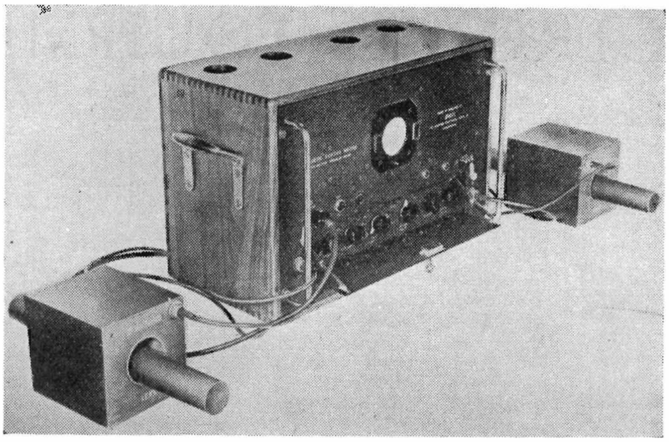
THIS instrument is designed for comparing ferro-magnetic components made under mass production conditions, or for the critical analysis of individual samples by comparison with known test-pieces. The first function can readily be carried out by unskilled labour, the second requires skilled personnel.

The method employed is based on the measurement of the hysteresis characteristic of the material under examination, and the fact that the shape of a hysteresis loop varies with the composition of the material or its physical state.

The instrument consists of a bridge circuit, two arms of which contain the test coils, in which the standard and specimens to be tested are respectively inserted; the indicator is a cathode ray oscilloscope. When correctly adjusted, the oscilloscope trace is a horizontal line if the specimen being tested is identical with the sample. Should the specimens differ from the sample the traces vary in shape and this variation can be readily interpreted by a skilled observer. The sensitivity of the apparatus is such that small chemical differences in the make-up of the material and hardness differences in its treatment are definitely indicated.

The test coils are provided in pairs, the standard size being $\frac{5}{8}$in. internal diameter, for testing wires and bars of small diameter, and another pair 2in. diameter for longer samples. Coils of 6in. diameter for testing still larger specimens can also be supplied.

G.E.C., Ltd.,
Magnet House,
Kingsway,
London, W.C.2.



Marconi Output Power Meter

THIS audio frequency output power meter, illustrated below, covers a wide range of power and maintains its accuracy at both high and low frequencies.

Power is measured by a temperature-compensated constant-resistance multi-range rectifier voltmeter, the required input impedance being obtained by the

use of a tapped transformer and by a switched resistance-changing pad.

The power range is from 20μW to 10W and the impedance range from 2.5Ω to 20,000Ω; provision is made for balanced working.

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

Mains Portable Model *p*H Meter

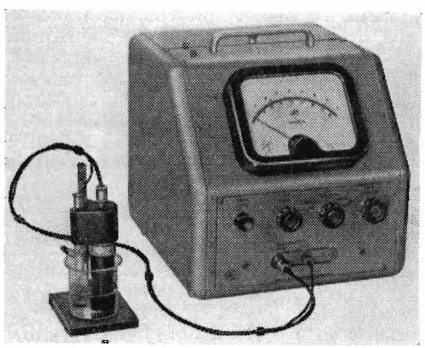
(Illustrated centre)

IT is claimed that the Pye *p*H meter combines extreme accuracy, stability and simplicity of operation. The reading is given directly on a large meter, there are only two controls to adjust each day, the readings are almost entirely unaffected by wide mains supply variations, the glass electrode is completely protected and virtually unbreakable, the reference electrode is of robust construction, and automatic temperature compensation is provided.

On opening the hinged lid at the top, an accessory box can be withdrawn; this contains the *p*H electrodes, bottles of buffer tablets, a graduated bottle, a beaker and a bottle of saturated potassium chloride solution. The electrodes and temperature compensation element are combined in a single unit and mounted on a stand; this unit can be raised or lowered at a touch.

The electrode arrangement is one of the most interesting features of the instrument, and the essential novelty consists in surrounding the glass electrode with a plastic sheath which acts as a protection and carries a temperature compensation element. The sheath, glass electrode, and reference electrode are attached to the top member to form a rigid unit. This unit slides up and down the electrode stand; it is immersed in the solution in one operation, and no awkward adjustments have to be made.

W. G. Pye and Co., Ltd.,
Granta Works,
Newmarket Road,
Cambridge.



Pulse Amplitude Analyser

IN the fields of nuclear research and radio chemistry it is often necessary to examine the amplitude distribution of pulses produced in an ionization chamber or other source. This may be done by the well-known method of employing an amplitude discriminator to count all pulses above a certain threshold level, successive counts being taken with different thresholds to obtain the integral distribution curve. A great saving in time and gain in accuracy may be made by the use of a Pulse Amplitude Analyser, which sorts the pulses into groups according to amplitude and counts the number received in each group. Five-channel and thirty-channel analysers have been developed in collaboration with the Atomic Energy Research Establishment, Harwell. The analysers do not include the ionization chamber or pre-amplifier, but are designed to handle pulses which have been amplified up to a level of about 2 to 30 volts.

The Pre-treatment Unit and Control Panel, which together carry most of the frequently used controls, are mounted on a sloping panel at the front of the equipment, the other panels being located on the vertical front and rear portions of the framework. The whole equipment is mounted on a welded steel trolley-base fitted with strong castors. The unit occupies a floor area 46 by 29in., with an overall height of just over six feet.

Southern Instruments Ltd.,
Fernhill, Hawley,
Camberley, Surrey.

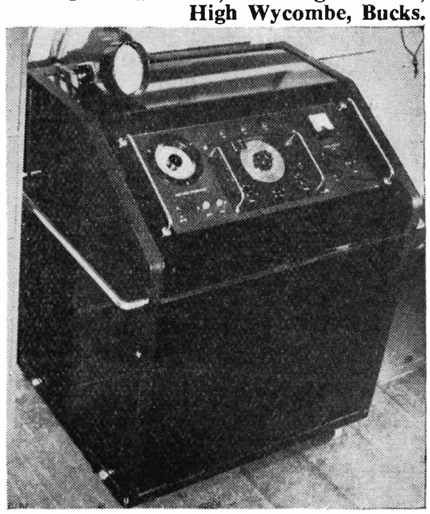
Ernest Turner's High Speed Stroboscope

(Illustrated below)

THIS instrument, designed by Ernest Turner Electrical Instruments Ltd., is a high power, high speed, short duration stroboscope.

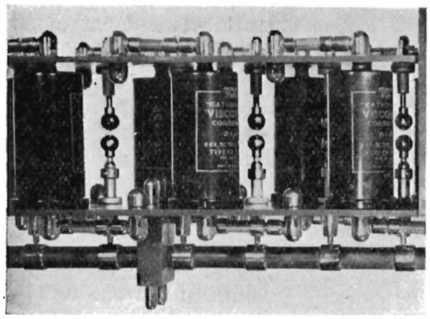
It has the following features: a frequency range of 100-4,000 second; with a flash energy of 4 joules per flash at repetition rates up to 3,000 per second, with a flash duration of less than 5 microseconds to 10 per cent of peak at all speeds measured photographically; it has a maximum normal operational duration of 1,000 consecutive flashes at any repetition rate, controlled by a pre-set timer (the duration can be increased by up to 100 per cent with some reduction in lamp life); the flash control is by self-contained calibrated oscillator (in three ranges), from external make contacts or from external sine wave or pulse frequency; and its operational control is from a panel or remote push button or external relay. The re-set button on the panel must be pressed before any run can be repeated, and the length of operation is controlled by a timer.

Ernest Turner Electrical
Instruments Ltd.,
Chiltern Works, Totteridge Avenue,
High Wycombe, Bucks.



ELECTRONIC EQUIPMENT

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



100kV Surge Generator Type 109SG

(Illustrated above)

THIS equipment was designed to provide a waveform conforming to British Standards Specification on Impulse Voltage Testing, No. 923.

It consists of a Marx circuit as modified by Goodlet, having 13 stages of 0.1μF each. These are charged in parallel and discharged in series, giving an output pulse of 100kV for an input supply of approximately 8kV D.C.

The output voltage is set by adjusting the first sphere gap with a micrometer control and then adjusting the remaining gaps simultaneously on a separate control to spark over at the same voltage. The output is conveniently variable over the range 30-100kV.

The wave shape can be altered by changing the forward and tail resistors, which are arranged with anti-corona spring mountings to simplify this operation.

Hazlehurst Designs, Ltd., 34a Pottery Lane, London, W.11.

Varley A.C. Solenoids

THE five types of A.C. solenoids made by this firm are designed with strokes ranging from ¼in. to 4½in. They are primarily intended for powering a great variety of valve mechanisms used on modern engineering equipment, as well as special duties such as the operation of brakes, pulse operations on packing machinery and on conveyor systems.

They are also suitable for providing power at a remote point from the operator or for automatic sequence switching control.

Care has been taken in design to ensure that normal production units maintain a high consistent performance with freedom from noise.

By means of the coil fitting, servicing becomes a very simple operation, while the provision of two sections coils allows a wide choice of pull characteristics.

The four larger size units are provided with fixing holes on four faces giving facility to the user within a wider scope.

Oliver Pell Control, Ltd., Cambridge Row, Woolwich, London, S.E.18.

Miniature Standard Cell

THE Muirhead type D-550-B standard cell is produced especially for use in educational establishments, where it is desirable that the internal construction should be visible. It is a standard cadmium all of the staurated acid type, but the electrode structure is such that it can be contained in a single glass tube. The electrical characteristics are comparable with those of abnormal type of cell.

Muirhead and Co., Ltd., Beckenham, Kent.

The Double X Fringe Area Television Aerial

THIS is a further development of the "Antex" television aerial, which is a combination of two of these aerials in a broadside array.

A standard "Antex" aerial is mounted at each end of a horizontal cross arm, the spacing between the two being approximately 0.4 wavelength. Interconnecting cables are supplied which are wired through the hollow cross arm to each aerial junction unit. These emerge from the arm at the centre, and are joined in parallel to the main cable by means of a small junction box. The length and impedance of the interconnecting cables are designed to provide the maximum gain, and to give correct impedance matching at the point of junction with the main feeder cable which should be of 75 ohms impedance.

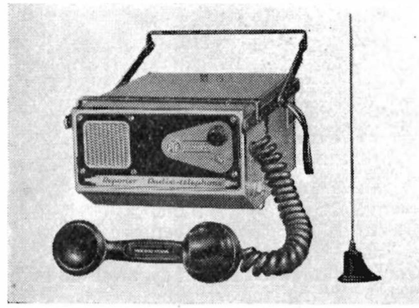
The gain over a standard dipole is 8.6db or 2.6db greater than that of the D6 three element aerial. The use of a broadside array provides ample bandwidth for full picture definition. The polar diagram shows that the aerial has a comparatively narrow beam width of 71 degrees at the half power points and is therefore good for elimination of interference. The front to back ratio is 13db.

Although the aerial is rather bulky it is light in weight and extremely rigid, and consequently does not present any particular difficulties in erection. It is recommended however that a strong mast be used in order to prevent any swaying in high winds. The construction of the junction units and aerial rods is similar to that of the standard "Antex" models, all connexions being accessible and completely waterproof. The aerial rods are of ½in. aluminium alloy tubing.

Antiference, Ltd., 67 Bryanston Street, London, W.1.

"Reporter" Mobile Radiophone

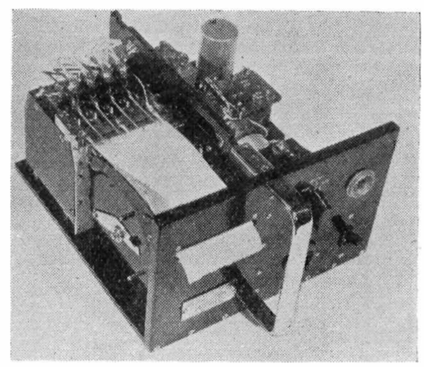
(Shown top right)



THE Pye "Reporter" mobile radiophone has been designed with the receiver, transmitter and associated power units all housed in one lightweight unit of 17lbs. It has a low power consumption of 3.0 amps for the receiver only, 3.5 amps for standby, and 4.0 amps for the transmitter. The set is intended for simplex working on the "press-to-talk" basis in either double or single frequency schemes, and is suitable for use in tropical climates.

The radiophone has a sensitivity better than 1.5 microvolts for A.F. output of 50mW, modulated 30 per cent at 400c/s. Alternative receiver bandwidths are available. It has a signal to noise ratio of better than 8db at one microvolt. The audio power output is 1 watt in 3 ohm loudspeaker, and the modulator response in the transmitter is ±2db from 200-3,000c/s, with an R.F. output of not less than 2.5 watts at 60Mc/s, and 1 watt at 185Mc/s. The frequency range of the equipment is 60-100Mc/s for type PTC 116, and 100-184Mc/s for type PTC 117.

Pye Telecommunications, Ltd., Radio Works, Cambridge.



Moving Coil Recorders

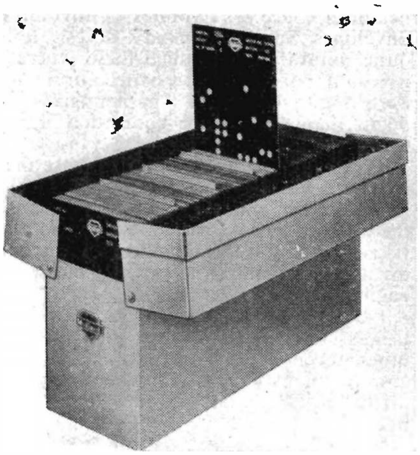
(Mark I Four-Pen Recorder illustrated)

KELVIN Hughes moving coil recorders employ a stiff strip suspension, which reduces the effect of vibration and pen friction to negligible proportions. Permanent and immediately-visible records are produced, either by using ink, or with Teledeltos paper (a dry electrolytic paper). Teledeltos paper is particularly suitable for mobile or industrial applications, as it never fails to write, and there is no ink to spill or pens to clean.

Complete recorders are produced in 1, 2, and 4-pen versions, and models are available for both mains and 12 volt D.C. operation. A 7-pen ink unit is also available. The trace width is 4cms. on the 1-pen recorder, and rather less on the multi-pen recorders. Coil units are obtainable having a frequency response which is level from zero to 90c/s.

Fixed pens can be fitted in addition to the moving pens, and these make possible the recording of additional information, such as time signals, the moment of operation of micro-switches, etc.

Kelvin and Hughes (Industrial), Ltd.,
2 Caxton Street,
London, S.W.1.



Test Card Container for Mullard High Speed Valve Tester
(Illustrated above)

A ROBUST steel container is now available for storing the test cards supplied with the Mullard High Speed Valve Tester which was reviewed on page 440 of the October 1950 issue. This container, which is finished in grey Dimenso to match the instrument, is designed to hold comfortably 600 cards, a quantity sufficient for testing about 750 distinct valve types. Space is also available for approximately an extra 100 cards in addition to the standard pack.

The container is divided into six separate compartments to facilitate the rapid finding of any individual card from the pack, and it is fitted with a dust-proof lid so that the cards are kept free from dirt and moisture. The steel partitions extend above the top of the cards, and are so arranged that if any one section is not completely filled, the cards still remain upright and easily accessible.

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

New G.E.C. Cathode Ray Tube for Television

THE General Electric Co., Ltd., announces the introduction of two new 12in. cathode ray tubes with aluminized screens, for television purposes.

The new tubes differ from the earlier 12in. tubes in that the screen face is much flatter (radius of curvature 700 mm.) and they can be used at H.T. voltages up to 10,000, against a previous maximum of 8,000.

The screen colour is white and the list price of both types of tube is £12 15s. plus £6 12s. 8d. purchase tax.

Type 6705A has a 6.3 volt, 0.5 amp. heater and type 670A a 10.8 volt, 0.3 amp. heater.

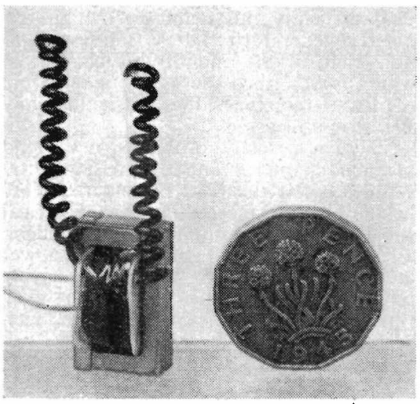
The General Electric Co., Ltd.,
Magnet House,
Kingsway,
London, W.C.2.

A New Frequency Recorder

GEORGE KENT, LTD., have developed an instrument for recording the frequency of electrical power supplies from a prototype originally designed for use in the firm's own Research and Development Department. Where an industrial process is dependent on the reception of current at a steady frequency, within certain limits, a continuous record of variations in the supply frequency is essential for accurate process control.

The circuit of the instrument is basically a Wien bridge. The resistors and capacitors have the values necessary to provide the required range of the instrument, usually 47 to 51 cycles per second. Mechanically coupled slidewire contacts work in tandem, which balances the circuit until no current is passing through the galvanometer, according to the null-point method of measurement. The scale of the instrument is approximately linear. Accuracy is of an order of ±0.03 cycles per second over the whole range. The recorder is sensitive to changes in frequency of less than 0.01 cycles per second. While the range 47 to 51 cycles per second is normal with this new instrument, the circuit values can be adjusted to cover other small ranges of frequency of the same order.

George Kent, Ltd.,
Luton,
Beds.



Miniature Transformers
(Illustrated above)

MESSRS. John Bell and Croyden have developed a new type of miniature output transformer, which they believe to be the smallest component of its type on the British market.

The transformer has a primary inductance of 28H at 200mA D.C. and 12H at 1000mA. It has a turns ratio of 50-1. The latest type F laminations, hydrogen annealed, are utilized, as is also a specially moulded bobbin.

John Bell and Croyden,
117 High Street,
Oxford.

Millivoltmeter
(Illustrated above)

THE Inter Electron Industries valve voltmeter, type 1277, is capable of measuring voltage between the limits of .0001V and 300V in the frequency range of 20c/s to 3Mc/s. The input impedance is 10mΩ shunted by 20pF and the accuracy is stated to be ±2 per cent up to 500kc/s and ±3 per cent between 500kc/s and 3Mc/s. Facilities are also provided for making power measurements in the range of −60 to +60db. In order to achieve stability of performance negative feedback is employed and all D.C. supplies are stabilized.

This instrument can also be used as a wideband amplifier or pre-amplifier giving a gain of approximately 500.

Inter Electron Industries,
7 Chilton Street,
London, W.1.

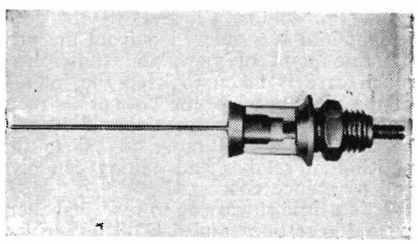
Erie Type 135 Miniature Trimmer
(Shown below)

THE Erie type 135 trimmer has been specially developed for service requirements, and the makers claim that it is the first fully sealed and tropicalized trimmer to be produced in this country.

It is designed to operate over a temperature range from −50°C to +100°C, and the seal is effective against vacuum and a pressure of two atmospheres. Provision is also made for a panel-seal.

The trimmer has a maximum diameter of 0.5 inches, and has capacitance range of 1-12pF and 3-50pF. The method of adjustment is by screwdriver slot.

Erie Resistor, Ltd.,
Millora Works, Beevor Road,
South Denes, Great Yarmouth.



BOOK REVIEWS

"Television" Volumes V and VI

461 and 422 pp. respectively. Published by R.C.A Review, Radio Corporation of America. 1950.

THE title of the books should really be "American Television," or even "R.C.A. Television" because they consist of a collection of well written articles by R.C.A. engineers, and have almost no reference to any work outside R.C.A. No attempt is made to put them in any technical order, there are no chapters, and the articles appear, one after another, each being complete in itself. All are reprints.

The standard of the work is, of course, very high, and the books represent an enormous effort in research and development.

Not many of the articles are of immediate use to the British engineer in his work, those on high efficiency scanning systems being probably the biggest exception. These articles by Otto H. Schade, and one by A. W. Friend, a summary of which is in volume V, were published in R.C.A. Review and have become standard references for engineers engaged on the design of scanning generators.

Naturally the data and examples refer to American standards and materials, and have to be modified drastically to fit other standards, but they nevertheless are of great value in the understanding of scanning problems and methods of overcoming them, and are probably the most up to date and complete articles on the subject published. They also go much farther into energy recovery and linearity than anything so far published here, probably because the American problem is so much more difficult, with higher frequencies, wider angle scanning and generally much higher E.H.T. than the British.

A considerable part of each book deals with U.H.F. problems, and shows other problems U.S. designers must face and overcome.

R.C.A. colour systems are also dealt with at some length in each book in an interesting manner.

The fundamental articles such as those on the "Sensitivity of the Human Eye" and "TV Electro-Optical Characteristics," are very interesting indeed, and help to give an understanding of the basic TV problem of getting an image from its source to the brain of the viewer.

The article on "Simplified Television for Industry" in Volume V should be of great value to the growing body of amateurs who are interested in amateur television transmission, as it gives circuits for a complete system using the 2in. iconoscope 5527, and needs almost no modification to make it fit the amateur "Standards" so far used.

"Television: Techniques and Applications" in Volume VI, gives a very good insight into U.S. television from the programme point of view, and shows how much care is taken to keep the interest of the viewers while the "soap" is mentioned. It would appear that films will be used more and more to utilize the polish that retakes and editing can give and to reduce cost.

It is a little staggering to read that there were 106 stations and 6,492,000 receivers on August, 1950, and that there were another 351 station applications pending.

Both volumes are well printed, with clear script, diagrams and photographs, and are up to the R.C.A. Review standard.

C. H. Banthorpe.

Basic Electronics

By R. G. Kloeffler and M. W. Horrell. 435 pp. John Wiley & Sons, Inc., New York. Chapman & Hall, Ltd., London. 1949. Price 40s.

THIS book represents an attempt to cover a very broad field. The first chapter, entitled "Physical Concepts," is introductory and deals with the nature of the electron, and electron ballistics. The next nine chapters deal in an orthodox way with valves and valve circuits, and are quite a sound introduction to the subject. The last of these chapters entitled "Modulation and Detection" is somewhat sketchy. The subject of amplitude modulation is treated in some detail, frequency and phase modulation are dismissed in two pages as "beyond the scope of this text book." The usual detectors for A.M. are described clearly and adequately. The use of a Foster-Seeley discriminator for F.M. detection is again dismissed as "beyond the scope of this book."

The remaining seven chapters suffer from an attempt to cover too wide a field, the subjects ranging from electrical conduction in gases, crystal rectifiers, photo-electricity, television (dismissed in two pages and illustrated by a singularly unhelpful diagram on p. 406) to, in the final chapter, x-ray tubes and very high frequency generators. It is interesting to note that, at the end of this chapter in which is described the cavity magnetron, the list of references does not include any British publication.

There is a set of problems at the end of each chapter. These are usually too simple to test the reader's understanding of the chapter, merely involve numerical substitution in a formula to be found on an earlier page. Typical is "a power amplifier requires 5 watts of driving power to produce an output power of 60 watts. What is the power gain in decibels?"

S. S. D. Jones.

Advanced Plane Geometry

By C. Zwikker. 299 pp. 273 figs. 1st edition. North-Holland Publishing Company, Amsterdam. 1950.

THIS book has fascinated the reviewer since he first opened it. This is partly because of the number of interesting ideas which appear in it, and the style is generally good. It is partly because there is a very valuable and interesting collection of properties of a large number of curves important in pure science and in engineering, and also because these properties are all proved and described in terms of complex numbers instead of cartesian co-ordinates.

More than these by themselves, the reviewer believes the fascination to be that the complex number method enables the author to cover under one heading an extraordinary variety of topics which are usually to be found in various books. The first few chapters on ratios and conic sections give an insight into the projective properties of these curves as well as useful practice in the use of complex numbers. Subsequent chapter headings are: Evolutes, Involutes, Envelopes, Spirals, Kinked Curves. It is quite natural to introduce these whereas it would not be if cartesian co-ordinates were used. Another chapter gives in detail many important conformal transformations and orthogonal curves.

This book is advanced in the sense that it goes beyond the geometry usually put in books for engineers, but not because the methods are abstract or elaborate. It is strongly recommended to anyone involved in the theory of electrical engineering.

Finally a word of praise to the publishers who have shown in this and other recent publications that they are among that small group who can print mathematical books clearly and intelligently.

G. J. Kynch.

Electron-Tube Circuits

By Samuel Seely. 529 pp. McGraw-Hill Publishing Co., Ltd. 1950. Price 51s.

THE use of electronic tubes is spreading into ever wider fields of application. In consequence, the number of circuits for different purposes whose use is becoming standard practice is steadily increasing. Professor Seely has assembled together in this volume a most valuable collection of such circuits, many of which have been difficult to find in the past without extensive bibliographic research.

Following an introduction to the characteristics of vacuum tubes when used as circuit elements, about a third of the book is devoted to amplifier circuits, the conditions in which each can best be used being very well brought out. A further quarter deals with oscillators, including four chapters on relaxation oscillators and the circuits used to produce such special wave-forms as are used for time bases. Three chapters are concerned with different methods of modulation and demodulation. A particularly good description is given of rectifying circuits and their regulation and control, and numbers of circuits for electronic computers, scalers and measuring instruments are discussed. The highly specialized circuits used in microwave work are not included.

The operation of each circuit is analysed, the approximations which are often necessary being clearly indicated. To keep the book within manageable proportions it has been necessary to avoid extensive discussion of the mode of action of electronic devices themselves. For example, it is possible to spend many pages in considering the means of initiation of the discharge in the ignitron, but the basic information required for an understanding of circuits using ignitrons is condensed into a couple of sentences showing the positive role of the ignitor rod in starting an arc at any desired instant, as contrasted with the negative role of a thyratron grid which prevents the formation of an arc. Nevertheless, useful practical details of the limits of operation, power handling capacity and so forth of the various electronic devices are included.

The index could usefully be extended somewhat in a later edition; thus for example, sanatron and phantastron circuits, though each having a complete sub-section, occur in the index only as sub-headings under "Delay Circuits," and sinors, though they are frequently used and are probably unfamiliar to many using the book, do not appear in the index at all. This is, however, a very minor criticism of a book which will undoubtedly be immensely useful to anyone seriously concerned with the use of electronic devices.

J. H. FREMLIN.

The Wireless and Electrical Trader Year Book 1951

22nd edition. 292 pp. The Trader Publishing Co., Ltd. Price 10s. 6d.

IN the 1951 edition of this year book considerable space has been devoted to television data designed to meet the needs of dealers in the areas in which the new television stations are to be opened later this year. This includes condensed specifications of current commercial television receivers (with such valuable facts as valves used, I.F. values, etc.) and information on valve and cathode-ray tube base connexions, with over 200 valve base diagrams. Other time-saving data range from specifications of current radio receivers, legal information and a directory of trade associations to a new section on TV test equipment and notes on licencing requirements as they affect the retailer.

Microwave Electronics

By John C. Slater. 406 pp. 91 figs. Bell Laboratories Series. Macmillan & Co., Ltd. 1950. Price 45s.

THIS is a book of considerable and lasting merit by the Head of the Department of Physics of the Massachusetts Institute of Technology, U.S.A. The outstanding value of the book lies in its unified treatment of apparently different electronic devices such as klystron and magnetron oscillators, travelling-wave amplifiers, linear accelerators, cyclotrons and synchrotons. By analysing these devices from a consistent point of view the author has been able to throw new light on their mode of operation and to bring out many points of similarity in behaviour.

The treatment is fundamental and mathematical in character, utilizing with great elegance and skill the theory of orthogonal functions as originally applied to microwave circuit problems by Hansen of Stanford University and Schwinger and others at the Radiation Laboratory, M.I.T.

The material presented is based largely on war-time research by the author on magnetron development at the Radiation Laboratory and the Bell Telephone Laboratories, following the pioneering work done in this country by Oliphant, Randall, Hartree and others, and includes original work by the author on linear accelerator design.

The book will probably be of greatest interest to the mathematical physicist, but it will also be of use to engineers engaged in the development of microwave equipment since its generality of treatment will often lead to the solution of new problems. Minor criticisms are the absence of quantitative information and the lack of detailed references in the text. Nevertheless in the reviewer's opinion these disadvantages are far outweighed by the gain in clarity and coherence made possible by the author's unified treatment of the subject.

W. J. BRAY.

"Avo" Valve Testing Manual

168 pp. Automatic Coil Winder & Electrical Equipment Co., Ltd. 1950. Price 15s.

THIS volume, although essentially an instruction manual to be used with two popular valve-testers, possesses several features which rate it worthy of review as a technical publication.

It is a model manual in that it shows the operator not merely how to set the controls to obtain a reading but also the background which will enable him to appreciate what he is measuring, any special difficulties that may arise, and general servicing of the instrument.

The introduction explains a preference for valve-test figures related to valve-makers' data rather than as mere figures of merit, and the consequent problem of providing stable testing voltages easily and economically, which led to the use of A.C. rather than D.C. electrode voltages. The original "Avo" Valve Tester (AVT) worked on the static zero bias mutual conductance figure, but modern performance figures cover a wide range of anode, screen and grid voltages and the more recent "Avo" Valve Characteristic Meter (VCM) was developed to enable the technique of rectified but unsmoothed A.C. to be used for g_m measurements at all points from zero bias to cut off.

The basic methods of checking characteristics of grid-controlled valves and of diodes and rectifiers are explained with the aid of schematic diagrams. Three types of insulation testing (cold and hot) and the operation of the anode/screen safety cut out are fully explained.

Among considerable detail (15 pp.) on setting up and testing are two particularly interesting and important features. On all-glass bases, particularly, it has recently become the practice of manufacturers to connect certain electrodes internally to pins which would otherwise be unused, and moreover these connexions may vary from time to time. It is accordingly dangerous to connect all such pins automatically to earth, and a simple initial procedure is given for finding to which electrode, if any, the "blank" pin is connected in order to obtain the correct setting. Secondly, the difficult problem of parasitic oscillations, which are frequently obtained with modern high-g_m valves, is discussed. The

BOOK REVIEWS (Continued)

reviewer has already raised this issue elsewhere,* having first noticed the effect when testing a miniature double triode (ECC 91) for match in the two halves. A very serious apparent unbalance was found in *all* valves of this type tested in the same way and one of the readings in each case was very unstable. Further investigation using a C.R.O. showed that one particular half always oscillated, the meter reading changing as a hand was brought near the valve, due to hand-capacitance. The effect is due to the long multiple electrode leads and their relatively high capacitative intercoupling thus giving the possibility of adding considerable external anode-grid capacitance when testing triodes, and thereby parasitic oscillation, particularly with modern high g_m types. Some experiments which the reviewer has carried out on octals and miniatures suggest that oscillation is likely whenever the measured mutual conductance exceeds 3-4mA/V in the case of triodes or of pentodes connected as triodes. The pentode connexion does not, of course, show any oscillation.

The makers use resistive stoppers where possible to prevent such oscillations, but these can only be fitted at odd points where they cannot possibly regulate current-carrying circuits, having considered all likely pin connexions. Wiring is also carefully laid out in other cases, but it is admitted that trouble may still arise with new valve types and the makers then suggest using a separate valve-holder adaptor which can be externally stoppered to suit the particular valve type. This is exceedingly clumsy and inconvenient, and the reviewer has found that a certain cure which does not interfere with the operation of the tester is to connect a damping capacitor from grid to cathode on the valveholder. For universal suppression a value of 100pF has been found satisfactory from every tag likely to be used as a grid to the panel frame, which is connected to the low ("cathode") end of the supply transformer and to its iron core, and earthed through the usual third wire on the mains lead.

The actual setting-up data is arranged in alphabetical and then numerical order, regardless of type or maker, in horizontal lines which refer to both the VCM and AVT and include a base connexion reference. The 67 large well-spaced data pages are printed on one side only, the reverse pages having merely column headings. Thus gummed supplementary data strips can be attached to the back of each sheet as issued, giving a good compromise between the durability of a fully-bound volume and the flexibility of a loose-leaf system (one minor criticism is that the valve type numbers all appear on the inside edge of each page only instead of being duplicated at both ends of each line). Another useful feature is a six-page civilian equivalents list of Service valve types, whereby the standard data can be used for the AR AU CV NR NT VR VT VU and VW series. The BVA Utility Equivalents are also included. The line data contain a number of errors, unfortunately, but these have been corrected in an amendment leaflet issued by the publishers.

Altogether this is an admirable instruction manual, so well produced that it will probably find its way on to library shelves rather than the bench of the workshop, where it is needed. The operator will then have to be satisfied with the varnished instructions card which is provided as a quick-reference guide.

J. C. FINLAY.

* *Finlay, J. C.: Testing Steep-slope Valves—Wireless World, March, 1951 (57) 108 (with a reply by Wilkins, S. R.).*

Short Wave Wireless Communication

By A. W. Ladner and C. R. Stoner. 5th edition. 717 pp., 417 figs. Chapman & Hall, Ltd. 1950. Price 50s.

IN this fifth edition of their book, the authors have continued the tradition of producing a text-book dealing with the general principles of short wave wireless communication. Chapters have been enlarged and brought up to date where necessary, and seventy-five new diagrams have been added. Three chapters, those on history, push-pull and diathermy, have been left out, and replaced by ones on sound and vision intelligence, waveguides and wireless circuits. But essential matter from the push-pull chapter has been incorporated elsewhere in the text.

Bibliography of Electron Microscopy

Edited by V.E. Cosslett, Ph.D., F.Inst.P., for the Institute of Physics. 350 pp. Edward Arnold & Co. 1950. Price 40s.

IN 1948 the Electron Microscopy Group decided to collate a centralized bibliography of their subject, and this was based on card indices which had been assembled over a number of years in various laboratories. The present book runs up to the end of 1948, and additions and amendments appear in the Group's bulletins from time to time.

The bibliography appears to be comprehensive, and should prove a useful reference volume.

Applied Electronics Annual 1951

Edited by R. E. Blaise. 263 pp. British-Continental Trade Press, Ltd. 1951. Price £2.

THE British-Continental Trade Press, Ltd., have produced the first edition of their "Applied Electronics Annual." This is divided into two sections, editorial articles and what is claimed to be a world directory. It seems to the reviewer that the directory is by no means complete, for far too many well-known firms making electronic apparatus are omitted.

In the section devoted to specialized journals on page 179, 'Wireless World" is credited to George Newnes, Ltd., instead of Iliffe and Sons, Ltd. Also the subscription rate is quoted as 9d. monthly —which is news to the reviewer. "The Wireless Engineer" and "The Wireless and Electrical Trader" are not mentioned at all.

If there is a second edition, these mistakes should be remedied, and an effort made to make the information included more accurate.

Radio Circuits

By W. E. Miller, M.A., M.Brit.I.R.E. 3rd edition. 120 pp. 64 diagrams. The Trader Publishing Co., Ltd. 1951. Price 5s.

THIS third edition of "Radio Circuits" brings the total number of impression to eleven, which is surely a testimony to the popularity of this book, which describes so very clearly the principles of circuiting, stage by stage from aerial to loudspeaker, in a practical manner.

The author is very careful to omit mathematics and difficult theoretical considerations, and assumes that his reader has little previous knowledge of radio. The operation of each individual section of a superheat receiver is carefully explained, and this new edition includes a new chapter on the "all-dry" portable receiver, the recent A.C./D.C battery sets, and band-spread and automatic tuning.

Radio Control for Models

By G. Honnest-Redlich. 116 pp. Harborough Publications. 1950. Price 8s. 6d.

THIS book, claimed by the publishers as the only one on this subject in the English language, covers the art from all aspects and is profusely illustrated. Aeromodellers are mainly catered for, but model boat builders who need help in taking their first steps towards radio control will also derive much benefit.

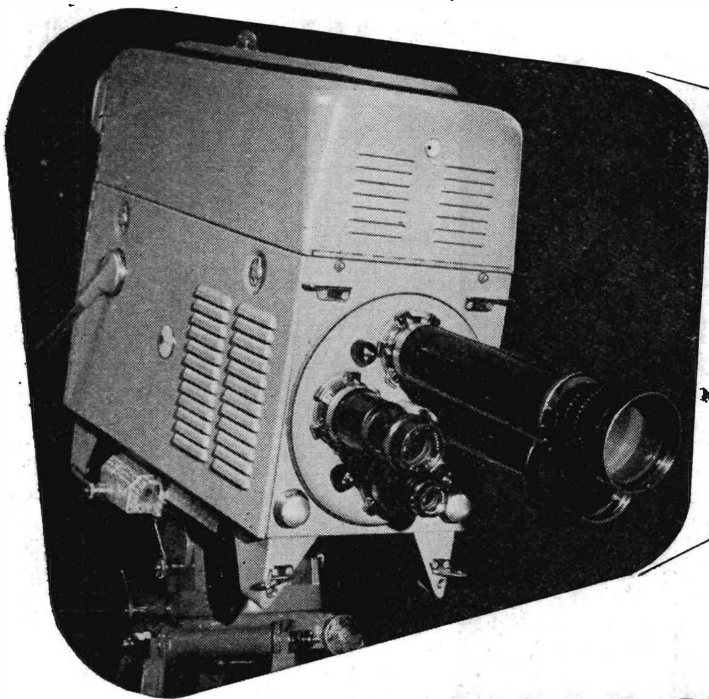
In separate chapters are described power supplies, transmitters, receivers, mechanical intergear and test equipment, as well as less detailed chapters on related subjects.

On the debit side, electronic nomenclature and definitions are rather loose, often bearing no affinity to B.S.I., and in some cases the line drawings are sketchy.

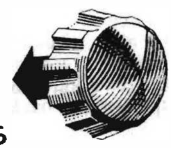
Electrical Engineers' Reference Book 1951

Edited by E. Molloy. 2,144 pp., 2,000 diagrams, 258 photographs. George Newnes, Ltd. 1951. Price 50s.

THE fifth edition of the Electrical Engineers Reference Book 1951 contains contributions by 62 specialists, being mainly treatises on a specific branch of an electrical subject. This edition has been divided into thirty-two sections, and new additions include: a summary of the Regulations for the proposed revised code for overhead lines; an article on radioactivity—"Radioactivity—Its Detection, Measurement and Industrial Utility," and two subsections on amplidyne control and ripple control for street lighting. The progress section is entirely new, and the electrical literature section has been revised and contains nearly 2,000 references.



LINKS
TRANSMITTERS
CAMERAS
AERIALS
STUDIOS



The Marconi Image Orthicon Camera

The Mark II television camera is used by the B.B.C. and will soon be delivered to the Canadian Broadcasting Corporation and the United Nations Organisation. It is also the camera chosen for use in the Festival of Britain Telekinema.

MARCONI television

Made by MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX.

—the only British firm to make complete equipment for television transmission

---

On with the Show!

COME... Come and see us at the Radio Show. You'll find us at Stand 60, ready to welcome old friends and new. (If this is not possible, we shall be happy to send you descriptive literature on any of our products in which you may be interested).

SEE... See the complete range of Stentorian extension speakers and chassis units and other famous Whiteley components.

HEAR... Hear the celebrated Concentric-Duplex High Fidelity Reproducer, combining exceptionally high quality with great power handling capacity.

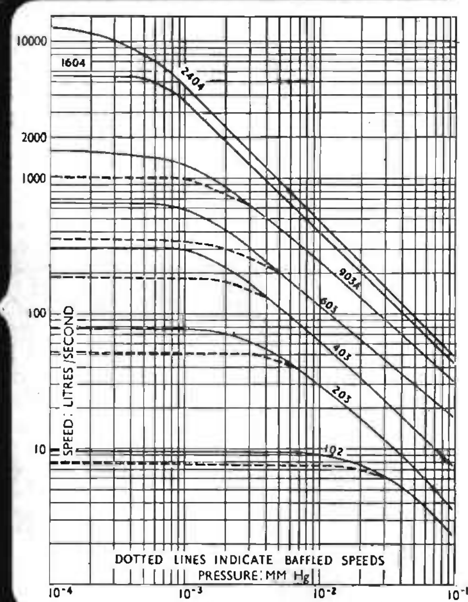
See and hear the "VIEW MASTER"—the Television set that anyone can build

Stentorian SEE YOU AT STAND 60

EXTENSION SPEAKERS

WHITELEY ELECTRICAL RADIO CO. LTD · MANSFIELD · NOTTS

'SPEEDIVAC' OIL DIFFUSION PUMPS



★ Integral " Booster " stage for high backing pressures eliminates inconveniently large backing line and large displacement backing pumps.

★ Combines high pumping speed and backing pressure performance with low heater inputs.

★ Water-cooled baffle valves maintain highest pumping speed with effective baffling and the operational advantages of an isolation valve.

★ Balanced multi-stage jet system gives highest pumping speed over a wide pressure range.

W. EDWARDS & CO. (LONDON) LTD.
LOWER SYDENHAM · LONDON · S.E.26

...For better vacuum service

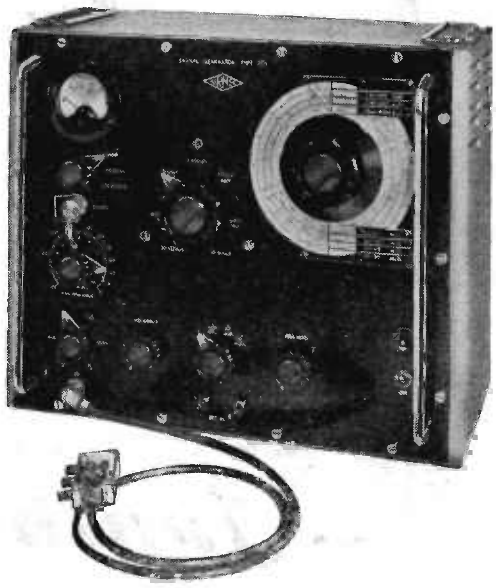
30 YEARS VACUUM EXPERIENCE

Telephone: SYDenham 7026 (8 lines) Telegrams: Edcohivac, Souphone, London.

H.F. SIGNAL GENERATOR TYPE 701

30 kc/s — 30 Mc/s

AIRMEC



The use of a two-valve tuned buffer stage which operates on all ranges of this Signal Generator, enables an excellent output waveform to be obtained from 30 kc/s—30 Mc/s. This arrangement also reduces spurious frequency modulation occurring with amplitude modulation to a very low level, and ensures that the oscillator frequency remains independent of the setting of the output and attenuator controls.

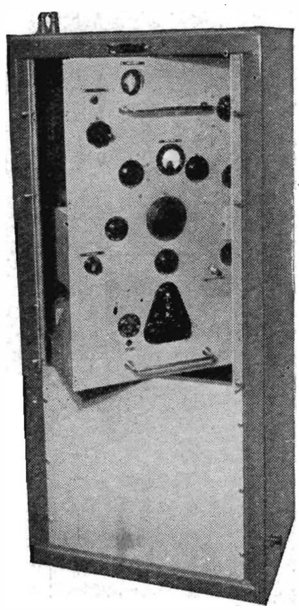
An automatic gain control circuit maintains the output voltage constant within ± 1 db over the whole frequency range, and a negative-feedback modulation circuit ensures a constant modulation depth and pure modulation envelope waveform under all circumstances.

Illustrated descriptive leaflets of this or any other Airmec instrument will be gladly forwarded upon request.

AIRMEC LABORATORIES **LIMITED**

HIGH WYCOMBE · BUCKINGHAMSHIRE · ENGLAND

TEL.: HIGH WYCOMBE 2060 · CABLES: AIRMEC, HIGH WYCOMBE



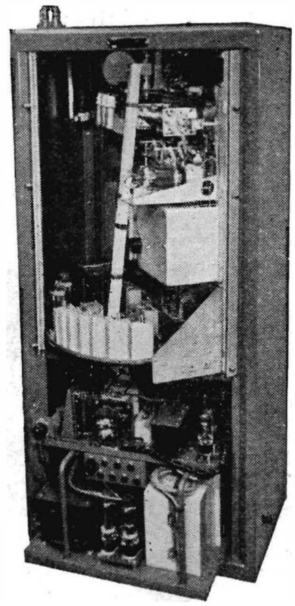
Chassis partly rotated.

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

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

COMMUNICATIONS

Redifon Radio



Chassis rotated and power units partly withdrawn.

Radio Communications Division

REDIFON LIMITED, BROOMHILL ROAD, WANDSWORTH, S.W.18

DESIGNERS & MANUFACTURERS OF RADIO COMMUNICATION & INDUSTRIAL ELECTRONIC EQUIPMENT Phone: VANdyke 7281

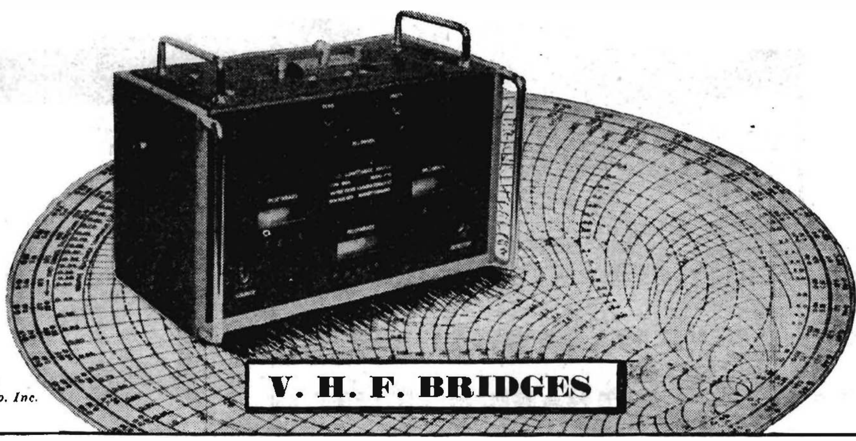


Diagram by courtesy of McGraw Hill Pub'g. Co. Inc.

V. H. F. BRIDGES

for balanced and unbalanced measurement at frequencies between 1 Mc/s and 250 Mc/s.

Wayne Kerr

THE WAYNE KERR LABORATORIES LIMITED, NEW MALDEN, SURREY. PHONE: MALDEN 2202

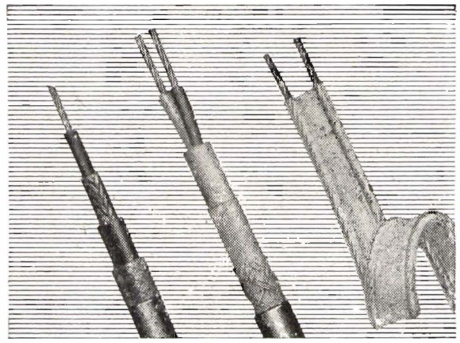
★ *The Basis of World Standards*

TELCON R.F. CABLES

Technical excellence supported by constant research and an unrivalled knowledge and experience of Radio Frequency Cable applications, ensures the continuance of the lead established by TELCON in this field.

Even before the introduction of Telcothene★ as a cable dielectric, an application pioneered by TELCON, a range of Radio Frequency cables with unique capacity and attenuation characteristics was produced, using Telconax.

Today, developments are still going on and the solution of any problems involving the application of Radio Frequency cables will be found in the wide range manufactured by TELCON.

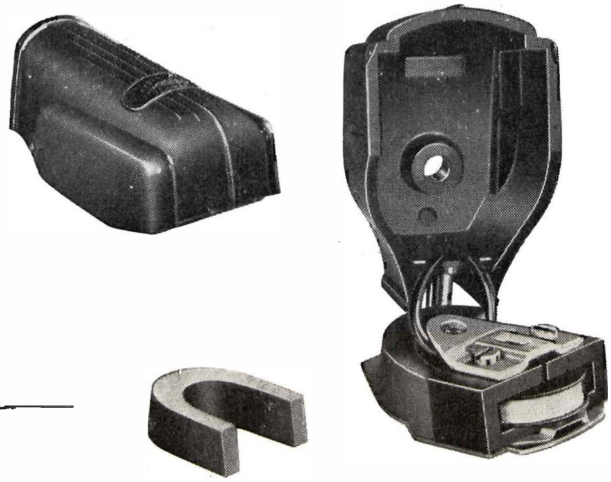


★ *Telcothene (Regd.)—Polythene processed by Telcon to provide specific characteristics*

Ask also for details of **TELCON METALS**

THE TELEGRAPH CONSTRUCTION & MAINTENANCE CO. LTD
Head Office : 22, Old Broad Street, London, E.C.2. Tel : LONdon Wall 7104
Enquiries to : Telcon Works, Greenwich, S.E.10. Tel : GREenwich 3291

PERMANENT MAGNETS



A COMPLETE SERVICE—
ADVISORY AND SUPPLY—
FOR SPECIALISED
INDUSTRIES

TOLEDO

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

DARWINS LTD
TINSLEY · SHEFFIELD · 9

D27

ALL-POWER

REGULATED POWER SUPPLIES

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.

ALL-POWER TRANSFORMERS LTD.

CHERTSEY ROAD, BYFLEET, SURREY.

TEL.: BYFLEET 3224.

CONSISTENTLY *Accurate*

PULLIN AC. DYNAMOMETER MULTI-RANGE TEST SET

An entirely self-contained instrument combining the functions of a precision indicating ammeter, voltmeter and wattmeter.

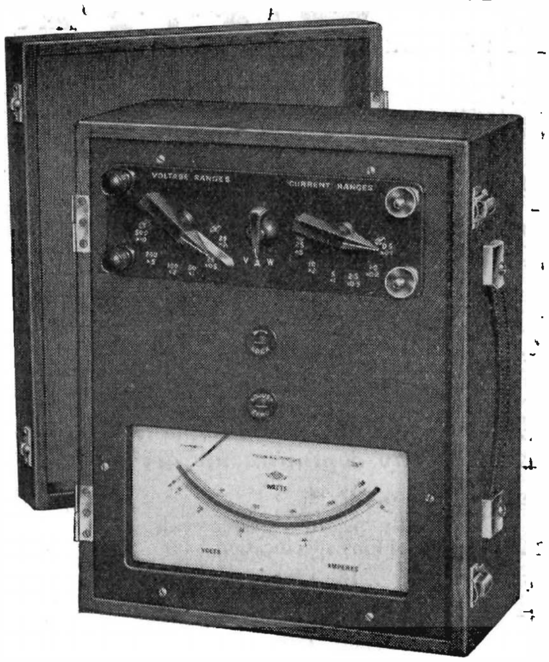
The P.D. 440 illustrated embodies the well-known Pullin iron-free dynamometer movement covering an extremely wide range to fine limits of accuracy. Supplied in polished hardwood case $10\frac{1}{2}'' \times 13\frac{3}{4}'' \times 7\frac{1}{4}''$, weight 17 lb.

5 Voltage—Ranges from 25 to 500 Volts AC or DC. Accuracy plus or minus 0.5%.

6 Ampere—Ranges from 0.5 to 25 (AC only). Accuracy plus or minus 0.5%.

30 Watt—Ranges from 12.5 to 12,500 (AC only). Accuracy plus or minus 1%.

MIP LTD



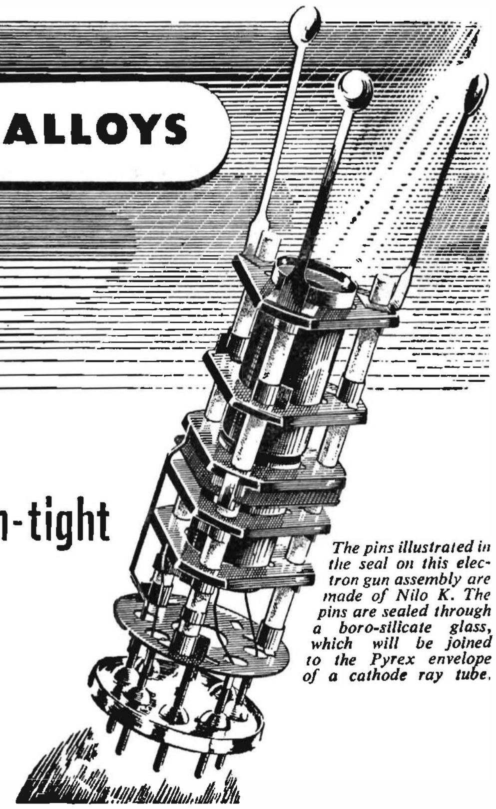
MEASURING INSTRUMENTS (PULLIN) LTD.

Electrin Works, Winchester Street, Acton, London, W.3. Telegrams: MIPULLCO EALUX LONDON. Tel. ACO 4651/3 & 4995

NILO ALLOYS

for

Vacuum-tight



The pins illustrated in the seal on this electron gun assembly are made of Nilo K. The pins are sealed through a boro-silicate glass, which will be joined to the Pyrex envelope of a cathode ray tube.

GLASS-TO-METAL SEALS

Single and multiple seals for a wide variety of purposes can be readily produced with the Nilo Series of alloys with controlled coefficients of thermal expansion.

- Nilo K has a coefficient of thermal expansion closely matching that of medium hard boro-silicate glasses over the range 20-500°C. These glasses are used in the construction of electronic equipment.
- Nilo 42 is the alloy used for cores of copper-covered wires for vacuum seals in lamps and radio valves.
- Nilo 48 and Nilo 50 are employed for seals with the softer glasses.
- Another alloy, marketed under the name B.T.H. No. 12 Alloy, is designed for use with soft lead and lime glasses.

For further information write for free copies of our publications "Glass-to-metal Seals" and "The Nilo Series of Low-Expansion Alloys".

HENRY WIGGIN & COMPANY LIMITED

WIGGIN STREET, BIRMINGHAM, 16.

Nilo is a registered trade mark.

36/NI/4

THE

BRITISH NATIONAL RADIO SCHOOL

ESTD. 1940

Now in our eleventh year and still—

NO B.N.R.S. STUDENT HAS EVER FAILED

to pass his examination(s) after completing our appropriate study course. Nothing succeeds like SUCCESS and what we have done already for so many of your colleagues, we can do again for YOU.

All our courses are conducted by correspondence, on INDIVIDUAL lines and our Syllabus includes preparation for the following examinations: A.M.Brit.I.R.E.; City and Guilds, Radio, Telecommunications, Mathematics and P.M.G. (theory only). Other courses include what we believe to be the finest RADAR course available anywhere.

Free Booklet (*please mention this advt.*) **from**

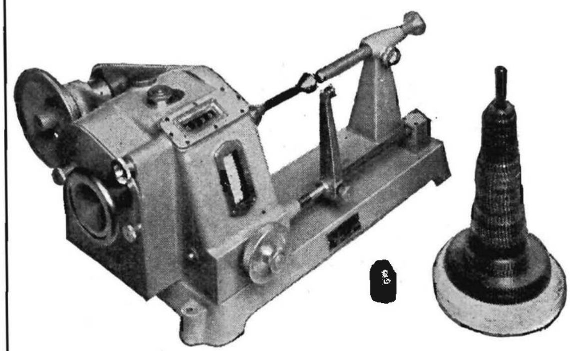
STUDIES DIRECTOR

BRITISH NATIONAL RADIO SCHOOL

66 ADDISCOMBE ROAD, CROYDON

Phone Addiscombe 3341

WELLINGTON WAVE WINDING MACHINE



Coils with diameters of $\frac{1}{4}$ in. up to 3 in. and with any width between $\frac{1}{8}$ in. and 1 in. may be wound either close or spaced, with a wave form of $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$, 1, 2 or 3 waves per turn of coil.

Many refinements are embodied, previously obtainable only on elaborate machines.

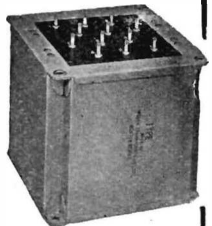
NEVILLE'S (LIVERPOOL) LTD.

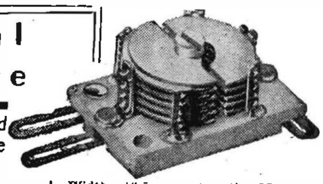
A Subsidiary of Aeronautical & General Instruments Ltd.

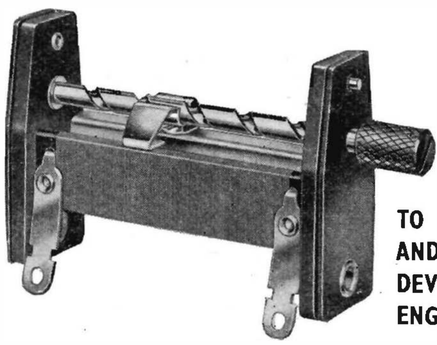
PURLEY WAY, CROYDON, ENGLAND.

Phone: Thornton Heath 3211

Cables: Instradio, Croydon.







INDEX TO ADVERTISERS

Acheson Colloids Ltd. 39
Air Control Installations 20
Airmec Laboratories 24
All-Power Transformers Ltd. 31
Amplivox Ltd. 43
Audigraph Ltd. 42
Automatic Telephone & Electric Co. Ltd. 14
Autoset (Production) Ltd. 34

B.B.C. Publications 36
Bell & Croydon, John 43
Belling & Lee Ltd. 16
Bradmatic Ltd. 38
Bray & Co., Ltd., George 37
British Insulated Callender's Cables Ltd. Cov. i
British National Radio School, The .. 40
British Physical Laboratories Ltd. .. 41
British Thomson-Houston Co., Ltd. .. 15
Bullers Ltd. 12
Burgess Products Co., Ltd. 38

Castle Engineering Co. (Nottingham) Ltd., The 39
Chapman & Hall Ltd. 323
Cinema-Television Ltd. 11
Cole Ltd., E. K. 3
Connollys (Blackley) Ltd. 34

Darwins Ltd. 28
Davis (Relays) Ltd., Jack 43
Derby & Co., Ltd. 38
Donovan Electrical Co., Ltd. 39
Du Bois Co., Ltd., The 27

Edison Swan Electric Co., Ltd., The 13
Edwards & Co. (London) Ltd., W. .. 24
Egen Electric Ltd. 42
E.M.I. Factories Ltd. 9
E.M.I. Institutes Ltd. 36
English Electric Co., Ltd., The 17

Furzehill Laboratories Ltd. 29

Gardner's Radio Ltd. 33
General Electric Co., Ltd., The .. 25

Harboro' Rubber Co., Ltd., The .. 41
Henley's Telegraph Works Co., Ltd., W. T. 41
Hifi Ltd. 43
Hivac Ltd. 36

"J.B." Service, The 42

Lyons Ltd., Claude 37

Marconi Instruments Ltd. 29
Marconi's Wireless Telegraph Co., Ltd. 23 & 44
Measuring Instruments (Pullin) Ltd. .. 31
Metropolitan-Vickers Electrical Co., Ltd. 10
Mica & Micanite Supplies Ltd. 41
Muirhead & Co., Ltd. 7
Mullard Ltd. .. .. .. 22 & 35
Murex Ltd. 30

Nagard Ltd. 37
Neville's (Liverpool) Ltd. 40

Oxley Developments Co., Ltd. 42

Painton & Co., Ltd. 30
Parmeko Ltd. 21
Partridge Transformers Ltd. 8
Pye & Co., Ltd., W. G. 32

Radiospares Ltd. 8
Redifon Ltd. 26
Reliance Mfg. (Southwark) Ltd. .. 42

Sangamo-Weston Ltd. .. .. Cov. iii
Sankey & Sons Ltd., Joseph .. Cov. ii
Standard Telephones & Cables Ltd. .. 19

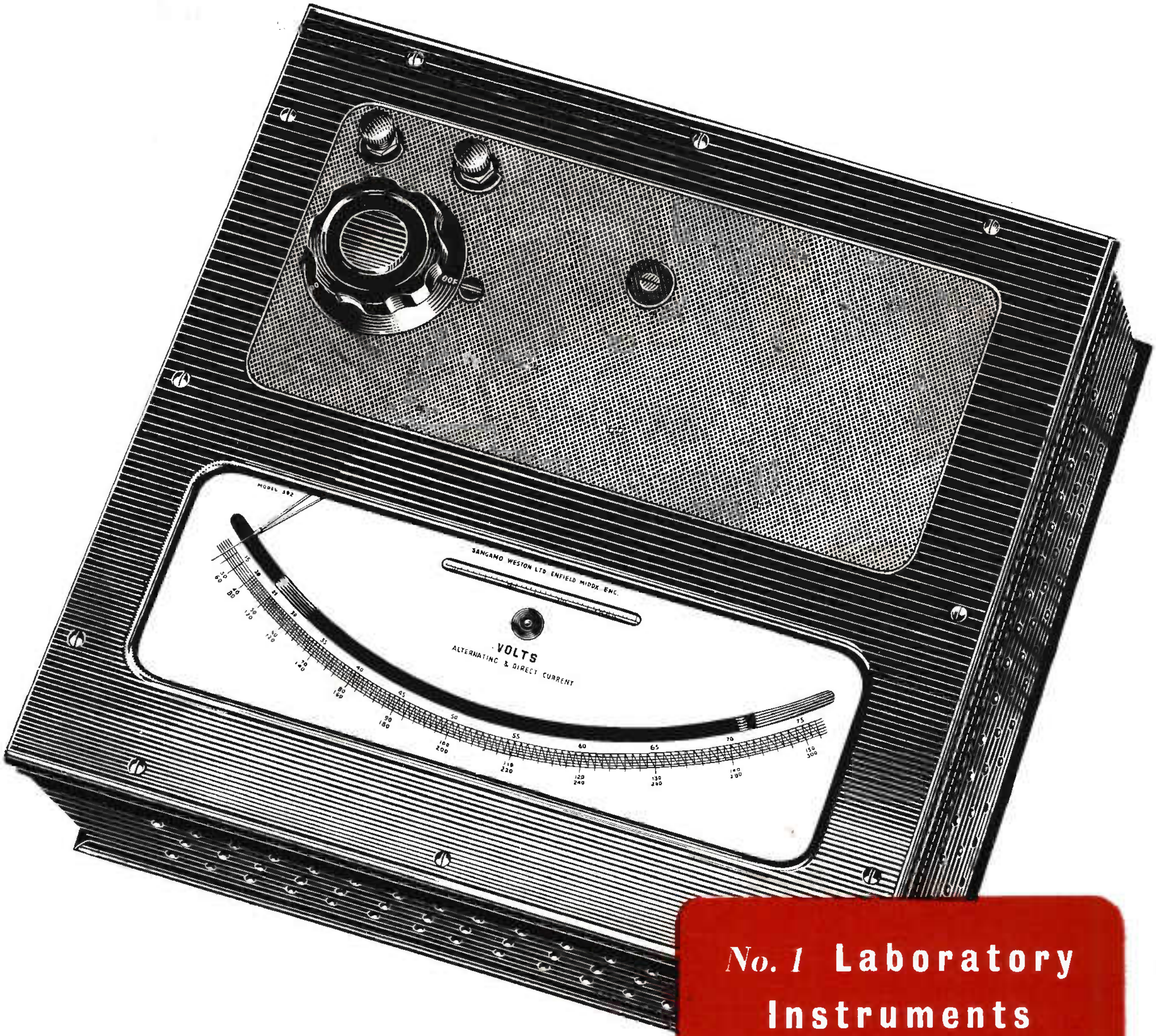
Telegraph Condenser Co., Ltd., The Cov. iv
Telegraph Construction & Maintenance Co., Ltd., The 28
Tufnol Ltd. 5

United Insulator Co., Ltd. 3

Vortexion Ltd. 33

Walter Instruments Ltd. 18
Wayne-Kerr Laboratories Ltd., The .. 26
Webb's Radio 32
Wells Brimtoys Distributors Ltd. .. 35
Whiteley Electrical Co., Ltd. 23
Wiggin & Co., Ltd., Henry 40
Wilkinson, L. 41
Woden Transformers Co., Ltd. 42
Wright, Bindley & Gell Ltd. 27

Printed in Great Britain by The Press at Coombelands, Ltd., Addlestone, Surrey, for the Proprietors, Morgan Brothers (Publishers) Ltd., 28, Essex Street Strand, W.C.2. Registered for Transmission by Canadian Magazine Post



No. 1 Laboratory Instruments

The experience gained from over 60 years in the design and manufacture of precision instruments is embodied in Weston Laboratory Standards. Endless care in the selection and ageing of materials and in the assembly and calibration of the instruments ensures the maintenance of the extremely high accuracy of 0·1%. Features include 12" Vernier Scale, magnetic shielding and self-contained thermometer. Full details of these instruments and of the full Weston range of switchboard, panel, first grade and sub-standard instruments are available on request.

WESTON
Electrical Measuring Instruments

SANGAMO WESTON LIMITED

Enfield, Middlesex. *Telephone : Enfield 3434 (6 lines) and 1242 (4 lines). Telegrams : Sanwest, Enfield.*

Branches : Glasgow · Manchester · Newcastle-on-Tyne · Leeds · Liverpool · Wolverhampton · Nottingham · Bristol · Southampton · Brighton