Electronic Engineering

Incorporating . . . ELECTRONICS, TELEVISION & SHORT WAVE WORLD

VOL. 20 No. 241 MARCH 1948 PRICE 2/-

Remember the ROLA G.12?

Remember the Rola G.12, most famous of all pre-war 12 in. speakers? Now, the G.12 is back with all the special features that made it so popular before, *plus* the more powerful Alcoma II magnet and *plus* special dustproof suspension completely protecting the coil and magnet gap. Thanks to the new magnet and up-to-the-minute manufacturing techniques, Rola are able to offer you in the new G.12 a speaker of even greater sensitivity and tonal brilliance than its predecessor combining more compact design with cleaner lines.

Write to-day for full particulars.

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CLASSIFIED ANNOUNCEMENTS

The charge for these advertisements is twelve words or less 5/- and 4d. for every additional word. Box number 2/- extra, except in the case of advertisements in "Situations Wanted" when it is added free of charge. 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 10th of the month for insertion in the following issue.

SITUATIONS VACANT

cancies advertised are restricted to persons or employ-nts excepted from the provisions of the Control of gagement Order, 1947.

ADING COMPANY requires junior development gineer (inter-B.Sc. standard), preferably with perience in radar or communications work. Com-ncing salary between £350 and £400 (according to perience), with excellent prospects for advancement. x 187, E.E.

RRANTI LIMITED require for Vacuum Physics boratory Physicists or Engineers, graduates or with uivalent qualifications, preferably with experience of ctronic vacuum work or U.H.F. valves. Application ms from Personnel Manager, Ferranti Limited, rry Road Edinburgh, 5.

CHNICAL WRITER. Electronic engineers seek tact with technical writer able to assist in prepara-n of sales literature. Box 203, E.E.

NIOR DESIGN ENGINEER required by vincial Radio Manufacturer opening new laboratory London area. Extensive laboratory experience in ign and development of radio and television eivers essential. Able to train and encourage junior ff. Good salary and prospects. Reply to Box 211, ., stating age, qualifications, experience and salary uired.

CHNICAL ENGINEER required for senior ition with Electrical Instrument Company. plicant should have sound electrical qualifications l his industrial experience should cover the design, nufacture and application of electrical measuring ruments and electronic testing equipment. plicant should state salary required and when he ld be free to take up appointment. North London a. Box 209, E.E.

VELOPMENT ENGINEER required for West ndon area. Must have industrial experience, ferably of audio frequency amplifiers, and education at least Inter. B.Sc. standard. Write, stating age, perience, education and salary required to Box , E.E.

CHNICAL REPRESENTATIVES required by nufacturers of electronic instruments and industrial uipment, including RF. heaters, preferably having a car. Write, stating experience, salary required, ., to Box 210, E.E.

AUGHTSMEN required for radar telecommunica-ns and electro mechanical instruments. West ndon area. Apply in confidence, stating age, details experience, and salary required, to Box 206, E.E.

CHNICAL ASSISTANT required by well-known npany, situated West London district, for investiga-n of improved processes in cathode ray tube nufacture. Degree in Chemistry or an equivalent alification desirable. Industrial experience on ilar work an asset. Applications, which should lude full details of training, experience, age and ary expected, should be addressed to Box 207, E.E.

ECTRONICS ENGINEER, H.N.C. or Degree ndard, 5-10 years' experience, required by leading gineering firm in Midlands for the design and struction of electronic vibration indicating and ording gear strain gauge recording apparatus, and neral development work of electronic laboratory. ve-day week. Reply, age, experience and salary uired, to Box 427, 8, Serle Street, London, W.C.2.

EST GEAR ENGINEER required for servicing ctrical test gear in inspection department. Apply Personnel Dept., E.M.I. Factories Ltd., Blyth ad, Hayes, Middx.

STRUMENT MAKERS required for prototype d similar work of an interesting nature. Five-day ek. Excellent working conditions. Apply in person, write to Personnel Dept., E.M.I. Factories Ltd., yth Road, Hayes, Middx.

ADIO ENGINEER required for technical investiga-n work on large-scale radio receiver and component oduction. Education up to Higher National rtification or City and Guilds Final. Apply by letter Personnel Dept., A/T. E.M.I. Factories Ltd., Blyth ad, Hayes, Middx.

RAUGHTSMEN required for jig and tool drawing ice. Must be familiar with electronic equipment nstruction. Manchester area. Apply, giving full rticulars of experience, qualifications and salary uired, to Box 213, E.E.

MANUFACTURERS OF WIRELESS EQUIPMENT in South East England require immediately two experienced Estimators. Applicants with workshop and/or drawing office experience on light electrical equipment, with previous estimating experience, should apply, stating age, qualifications, experience and salary expected, quoting Ref. 89 to Box 205, E.E.

ENGINEER REQUIRED to take charge of Type Approval and Life Test Laboratory. A knowledge of the necessary procedure is not essential but is desirable. The position is one of responsibility, and applicants should have had at least five years' experience in a senior position on the design of components, light electrical appliances or electronic equipment. State full particulars of experience, age and salary required to Box 201, E.E.

LEADING RADIO COMPANY requires the services of a fully qualified and experienced Communications Engineer as Chief Engineer in charge of Domestic Radio and Television Research and Development. Salary £1,200-£1,500 per annum. Age not less than 35 years. State full details of experience to Box 204, E.E.

TECHNICAL ASSISTANT required to take charge of electro-encephalographic apparatus. Must have experience in electro-encephalography and general knowledge of radio mechanics. Salary £500, rising by £25 to £600 per annum. Placement on scale according to experience. Non-contributory pension scheme recognised under National Health Service Act. Application form obtainable from Physician Superintendent, Crichton Royal Mental Hospital, Dumfries.

ENGINEERS required for employment on development of radar, communication and electronic equipment. Applicants must possess a degree in Engineering or its equivalent. Salary £400 to £600 per annum, according to qualifications. Reply, stating age, experience, training and qualifications, etc., to Cossor Radar Ltd., Wren Mill, Chadderton, Nr. Oldham, Lancs.

DESIGNER-DRAUGHTSMAN required for factory Northern area. Must be conversant with radar and radio equipment construction. Reply, stating age, full details of experience, training and salary required, to Box 214, E.E.

A SENIOR RADIO DEVELOPMENT ENGINEER is required by the South Western Division of a leading Radio Company. Candidates should have had practical experience in radar work and be capable of controlling sections developing radar and atomic energy electronic equipment. Commencing salary will be £600 upwards, according to qualifications and experience. Housing accommodation is likely to be made available in the near future to the person appointed. Full details should be submitted immediately.

The Company is also appointing a Junior Development Engineer (Inter. B.Sc. or equivalent). Candidates for this post must have had practical experience in radar and communications equipment design. The commencing salary will be £350/£400, with every prospect and facility for advancement. Full details of qualifications and previous experience in writing to Box 212, E.E.

ENGINEERS required for employment on mechanical design of radar, communication and electronic equipment. Applicants must possess a degree in engineering or its equivalent, and be capable of producing designs suitable for small and mass scale production. Write stating age, details of experience, training and qualifications, etc., to Cossor Radar Ltd., Wren Mill, Chadderton, Nr. Oldham, Lancs.

DEVELOPMENT ENGINEERS required by radio manufacturers in Essex for work on centimetric waves. Candidates should possess a University Degree, preferably with telecommunications as a subject. Age 25-35. Salary according to age and experience. Apply, quoting Ref. 91, to Box 215, E.E.

QUALIFIED MATHEMATICIAN required. At least seven years' experience in industry or Government establishment. Must have had experience in circuit analysis, etc. Write Box N5703 A.K. Advtg., 212a, Shaftesbury Avenue, W.C.2.

RADIO COMMUNICATIONS EQUIPMENT Electrical engineering and physics graduates are required for work in this field, preferably with experience in research and development in telecommunications and with a good Honours Degree. Apply by letter only to the Director, Research Laboratories of the General Electric Co. Ltd., North Wembley, Middx., stating age, experience and qualifications.

SITUATIONS WANTED

GRADUATE ENGINEER (Mechanical Faculty) with wide experience; managing director of big tele-radio-com. factory abroad; specialist in mass production, tool and machine fixture designing, time and motion study; thorough knowledge of limits and precision fittings for engineering, etc., now seeks appointment in London. Box 195, E.E.

PHYSICAL CHEMIST, own laboratory, high qualified, offers services for research and development work on physical or chemical problems. Box 217, E.E.

YOUNG ENGINEER, 21, B.Sc. (Hons.), with some experience of factory technique, keenly interested in telecommunications, desires progressive position in design or research work involving some academic application. Box 218, E.E.

EXPERT SHORTHAND-TYPIST Secretary desires change. Long experience of technical work in scientific industries. Box 219, E.E.

PHYSICIST, B.Sc., F.Inst.P. 38, experienced in electronic engineering and vacuum practice, is available for research in thermionics, vacuum physics applications, or instruments. Box 221, E.E.

BUSINESS OPPORTUNITIES

DIRECTORSHIPS OFFERED in small newly formed company (with two subsidiaries) to capable man expert on amplifiers and general service work. Ample scope with great possibilities. Capital required up to £1,000. Write Box 202, E.E.

BRITISH PATENT No. 565,206. It is desired to secure the full commercial development in the United Kingdom of British Patent No. 565,206 which relates to apparatus for transmitting pictures between spaced points, either by way of the grant of licences or otherwise on terms acceptable to the patentee. Interested parties desiring copies of the patent specifications should apply to Stevens, Langner, Parry and Rollinson, 5 to 9, Quality Court, Chancery Lane, London, W.C.2.

EDUCATIONAL

UNIVERSITY COLLEGE, SOUTHAMPTON.
Diploma in Electronics.

An advanced course of Honours Degree Standard, covering the entire field of Electronics, with special emphasis on Receiver Design and Line Technique, will commence at the beginning of October, 1948.

The course will be full time for one academic year. The College will grant a Diploma by examination to students who successfully complete the course. Entry qualification is normally a university degree or its equivalent. Further details may be obtained from the Assistant Registrar.

COMPLETE CORRESPONDENCE COURSE covering Amateur and C. and G.I. Examinations, consisting of 12 lessons. Send for particulars. Everyman's Correspondence College, 72, St. Stephen's House, Westminster, S.W.1.

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IN STOCK. Rectifiers, Accumulator Chargers, Rotary Converters, P.A. Amplifiers, Mikes, Mains Transformers, Speakers of most types, Test Meters, etc. Special Transformers quoted for.—University Radio, Ltd., 22, Lisle Street, London, W.C.2. GER. 4447.

POWER UNITS featuring small size 6 in. by 5 in, captive head terminals, plug type mains connector, on/off switch and indicator lamp and 6.3 volt 5 amp, Two types 250 volts 80 mA hum level 0.25 per cent., price £4; 350 volts 100 mA, price £4 10s. James S. Kendall, Assoc.Brit.I.R.E., A.M.I.R.E., 133, Osmaston Road, Birmingham, 17.

COMPONENTS and valves available at attractive prices. Send for list. Trade list available. Watts, 38, Chapel Avenue, Addlestone, Surrey.

EX-R.A.F. Loran Indicators with 5 in. electrostatic c.r.t. with time base. 26 valves including 6SN7, 6H6, 6SJ7 and calibrated 100 Kc. crystal, suitable for conversion to oscillograph, £10. Box 220, E.E.

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CLASSIFIED ANNOUNCEMENTS (Cont'd.)

ELECTRICAL CONTRACTOR has valuable stock for disposal. The items include conduit, switch gear, domestic fittings, fluorescent fittings, tubes, etc., etc., to the approximate value of £4,000. Write Box 216, E.E.

THE ENOCK PICK-UP is now available in limited quantities. Moving coil with precision made polished diamond stylus. Weight at needle point, $\frac{1}{8}$ oz. No resonances within the recorded range. Price (in Great Britain), £32 13s. 4d., inc. tax. Please send for particulars, or better still, let us demonstrate. Joseph Enock Ltd., 273a, High Street, Brentford, Middlesex (EALing 8103).

THE MORDAUNT Duplex Reproducer, as used in the ENOCK Instrument, is now available separately. Folded horn bass unit and new high note reflector of original design, giving exceptionally smooth response from 40-20,000 c.p.s. Even distribution over a wide angle. Reproduction has an "atmosphere" and realism hitherto unattainable. Price (ex works), 98 gns. Please send for full particulars, or better still, let us arrange for a demonstration. Joseph Enock Ltd., 237a, High Street, Brentford, Middlesex (EALing 8103).

COPPER WIRES, enamelled, tinned, litz, cotton, silk covered. All gauges. B.A. screws, nuts, washers, soldering tags, eyelets. Ebonite and laminated Bakelite panels, tubes, coil formers. Tufnol rod. Flexes, permanent detectors, earphones, etc. List S.A.E. Trade supplied. Post Radio Supplies, 33, Bourne Gardens, London, E.4.

ELECTRONIC ENGINEERING. 75 copies, June, 1941, to date. Apply J. Ramage, 45, John Street, Larkhall, Lanarks.

MAZDA CRM 91 Television Cathode Ray Tubes' £7 10s. each. Few only. 229, Hale Lane, EDGware 7312.

SHORTWAVE COILS, chokes and condensers, slow-motion dials and drives, chassis, panels, cabinets, nuts and bolts, rotary switches, electrolytics, miniature components, resistors, etc., etc. Extensive range of components. American and British valves, Vitavox speakers and microphones, Sound Sales feeder units and amplifiers, Gardner transformers, radio circuits and manuals, etc., etc. Eddystone stockists. Catalogue, 2½d. post free. Whatever you want, write City and Rural Radio, Constructional Engineers, 101, High Street, Swansea (Phone 4677).

QUALITY AMPLIFIER as recommended by G.E.C. and built to Mr. Williamson's specification. 7 valves. Partridge transformers, etc. Definitely the finest reproducer yet manufactured. 15 watts output. Price, £25 10s. Elec. motors with pick-up, 12-in. speakers, pre-amplifiers, also supplied. Details from R.T.M. Co. Ltd., "Laurel House," 141, Little Ealing Lane, W.5 (EAL. 6962).

TIME BASE UNITS, type 28. Brand new, containing 10 EF50's, 1 807, 4 EB34's, 11 potentiometers (6 with slow-motion drives), approx. 90 resistances, condensers, relays, Yaxley switch, etc. Complete in wooden packing case, bargain £4 15s. Carriage paid. V1907 5,000 volt rectifier, 4 volt fil., 7s. each. Power units, transformers, chokes and many other items. S.A.E. list bargains. Cross, 19, Riverside Road, West Kirby, Cheshire.

POTENTIOMETERS. A small quantity of Colvern can-corrected precision type 5,000 ohms linear 3½" diameter, ¼" or ⅜" spindle. £3 each. Rogers Developments Co., 12 Macclesfield Street, Shaftesbury Avenue, London, W.1.

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FACILITIES AVAILABLE for radio assembly work on amplifiers, radar and small radio chassis. Prompt deliveries, first-class work. Write R. T. M. C. Ltd., 141, Little Ealing Lane, W.5 (EALing 6962).

LOUDSPEAKERS—We carry on. Sinclair Speakers, 12, Pembroke Street, N.1.

LOUDSPEAKER repairs, British, American, any make, moderate prices.—Sinclair Speakers, 12, Pembroke Street, N.1.

FACTORY HAS TECHNICAL Staff and capacity available for manufacturing scientific or other articles in glass. Box 163, E.E.

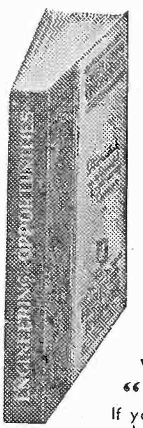
MISCELLANEOUS

WE WILL BUY at your price used radios, amplifiers, converters, test meters, motors, pick-ups, speakers, etc., radio and electrical accessories. Write, phone or call, University Radio Ltd., 22. Lisle Street, London, W.C.2. GER. 4447.

WEBB'S Radio Map of the World enables you to locate any station heard. Size 40 in. by 30 in. 2-colour heavy Art Paper, 4/6, post 6d. Limited supply on Linen, 10/6, post 6d.—Webb's Radio, 14, Soho Street, London, W.1. 'Phone GERrard 2089.

MORSE Practice Equipment for Class-room or Individual Tuition. Keys Audio Oscillators for both battery or main operation. Webb's Radio, 14, Soho Street, London, W.1. 'Phone: GERrard 2089.

PHOTOGRAPHY. We specialise in advertising and catalogue-photography, and in series photographs for instruction sheets. Our pictures tell the story. Behr Photography, 44, Temple Fortune Lane, M.W.11 (SPEedwell 4298).



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Similarly, engineers are using TUFNOL, a comparatively new material, with advantage to improve their products and plant. In practically every industry TUFNOL has proved to be the solution to tricky problems—as improved gear wheels, textile bobbins, aircraft pulleys, chemical trays and electrical insulators to name only a few of the thousands of different uses. Can TUFNOL improve your products or plant? Write for fuller details or ask for one of our technical staff to call on you.

- TUFNOL . . a comparatively new material. Made in the forms of sheets, tubes, rods, bars, angles and channels.
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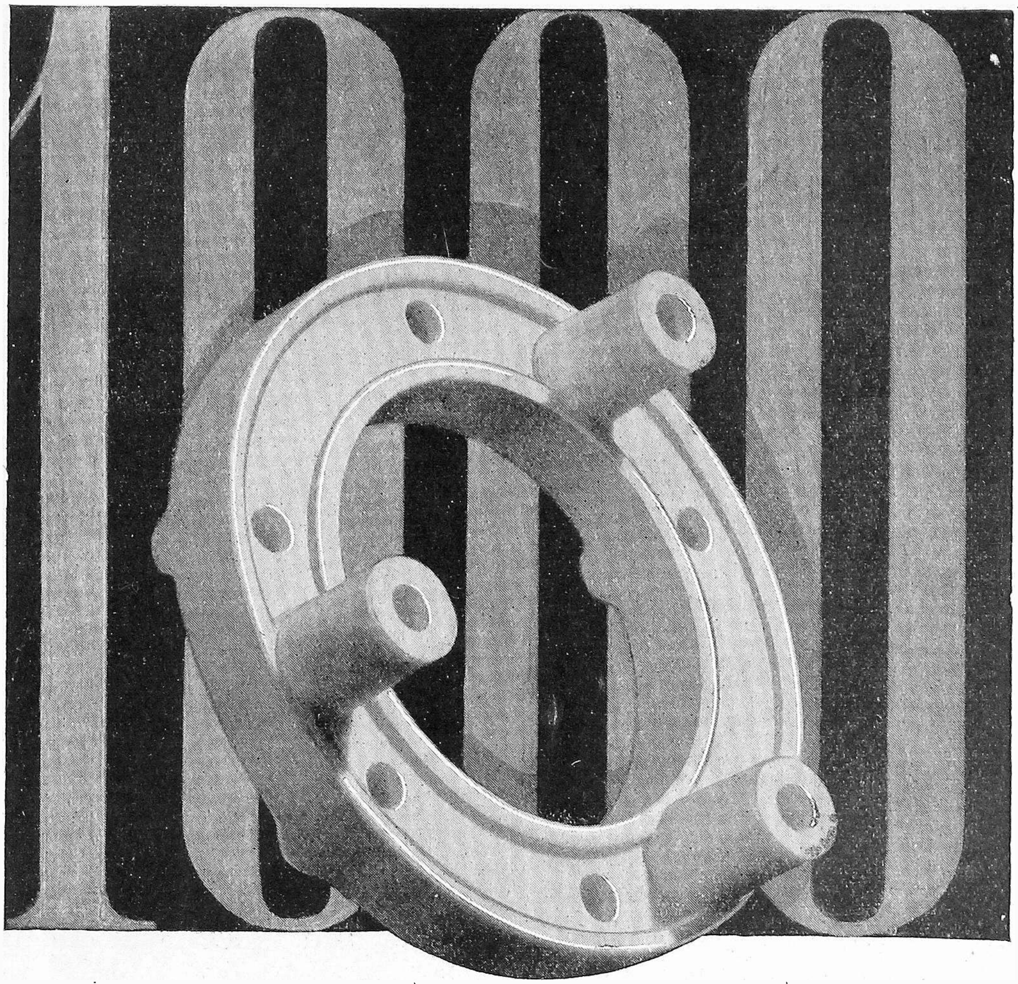

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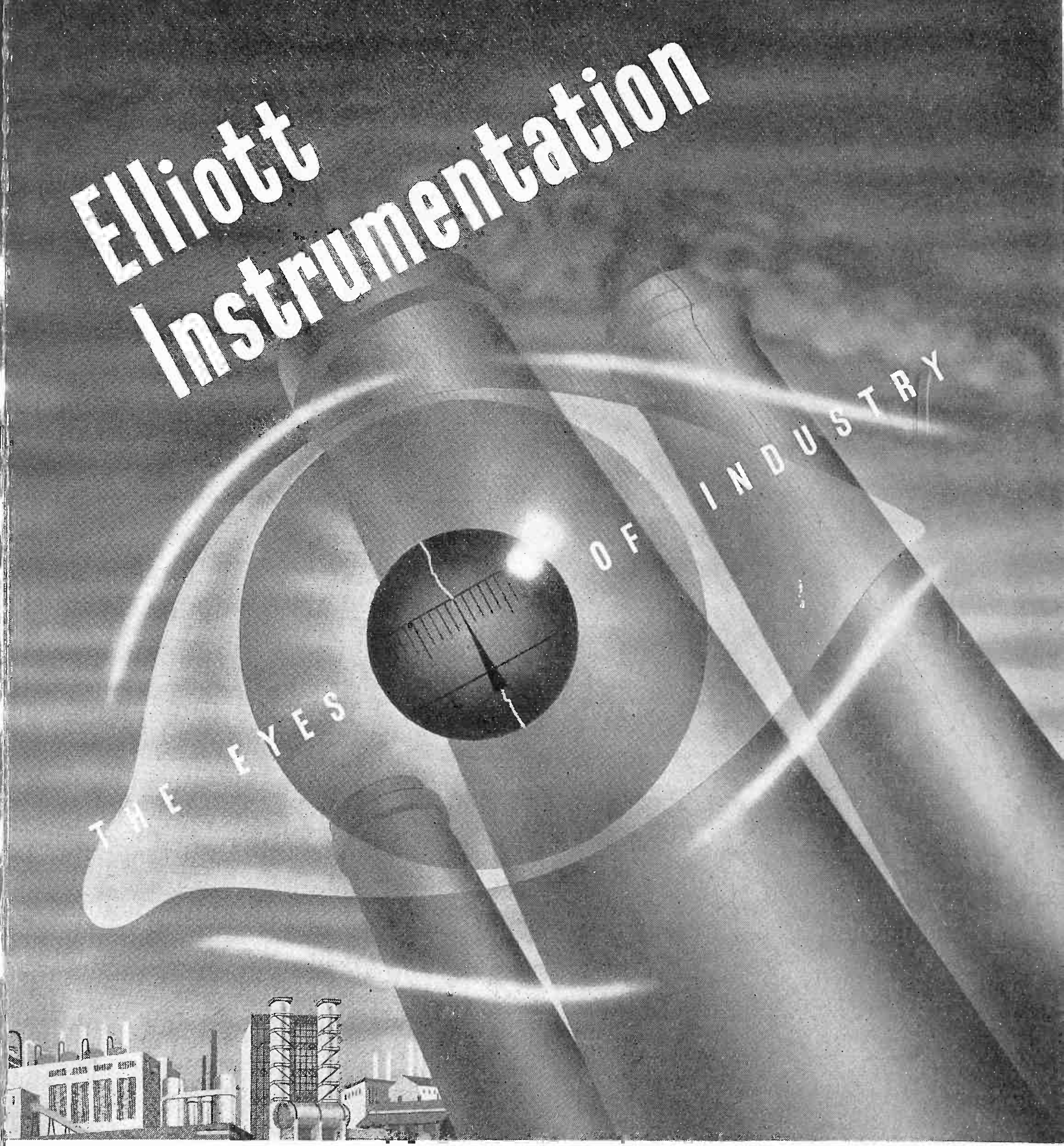
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Important News

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AND THIS COMMUNICATIONS RECEIVER CAN NOW BE SUPPLIED

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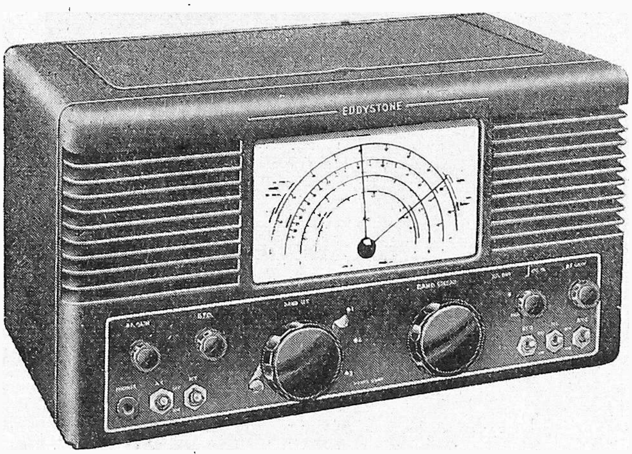

In addition, the manufacturers have improved their line production, enabling a reduction in cost to be made.

PRICE £39. 10s. NO PURCHASE TAX

This efficient general purpose short-wave receiver, is designed to meet the exacting requirements of Amateur-Band Communications.

Continuous Coverage from 31 to 1.7 Mc/s with Electrical Bandspread throughout. Eight Valves (plus rectifier). One R.F. and two I.F. Stages. Efficient Noise-limiter. 10, 20, 40, 80 and 160 metre Amateur Bands calibrated. Beat Frequency Oscillator. Flywheel Control on Bandspread. Vacuum mounted Crystal Filter Adapter for Battery Operation.

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A compact, highly sensitive instrument for measuring Insulation Properties and Leakage Resistance without destructive breakdown; also suitable for Moisture Determinations. A guard circuit is provided for proper elimination of surface leakages:

Range: 0.1 MΩ to 10,000 MΩ
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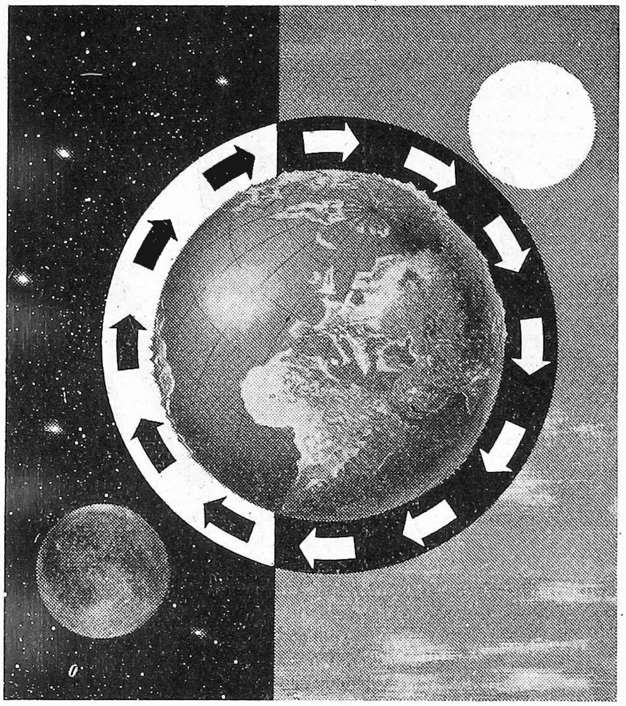

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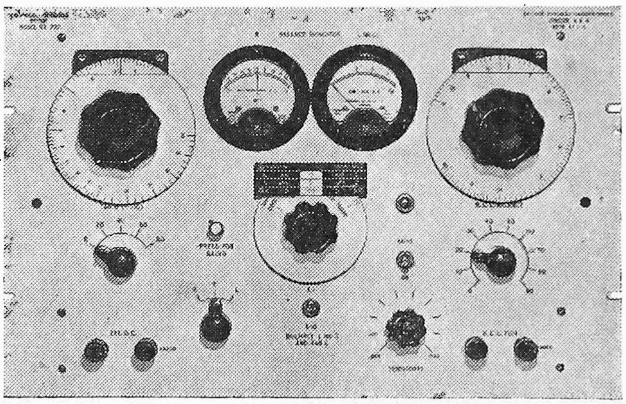

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This is a self-contained universal bridge which measures resistance at DC, Capacity and Inductance at 1000 Cycles. The necessary bridge voltage and null detectors are incorporated in the instrument. Measurements in condensers can be carried out with applied polarising voltage and inductances can be measured with superimposed DC.

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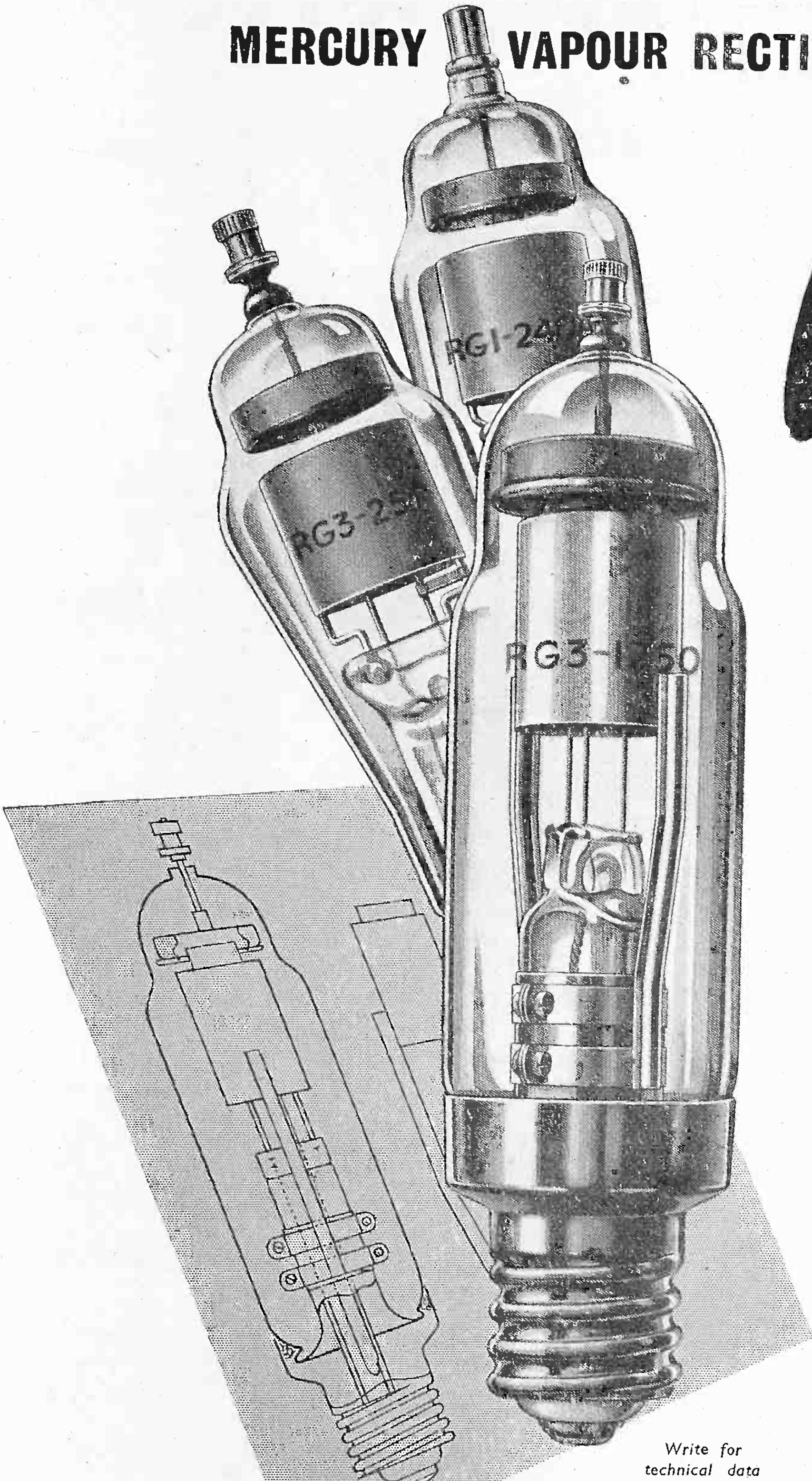
MERCURY VAPOUR RECTIFIERS WITH AN ASSURED *Long Life*



These three Mullard rectifiers owe their reputation for dependability to closely controlled manufacturing processes. Below are some of the reasons why more and more designers are specifying the "RG" range.

Stable Emission. The special double spiral filaments are so designed that the emissive coating is firmly keyed to the wire.

Long Life. The use of zirconium to eliminate "foreign" gases reduces positive ion bombardment of the cathode.

High Voltage Tests. All valves are subjected to rigorous back-arc tests.

RG1-240A

Peak Inverse Voltage	4,700 V max.
Mean Anode Current	250 mA max.
Two Valves in a Single-Phase Full-Wave Circuit will give 1,500 Volts at 500 mA.	
Filament Voltage	4.0 V
Filament Current	2.7 A

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Mean Anode Current	250 mA max.
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Filament Voltage	2.5 V
Filament Current	5.0 A

RG3-1250

Peak Inverse Voltage	13,000 V max.
Mean Anode Current	1.25 A max.
Two Valves in a Single-Phase Full-Wave Circuit will give 4,140 Volts at 2.5 amps.	
Filament Voltage	4.0 V
Filament Current	7.0 A

Write for technical data on these and other Mullard valves

B. I. F.

We will be exhibiting at Olympia, Stand No. H. 45

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THERMIONIC VALVES & ELECTRON TUBES

THE MULLARD WIRELESS SERVICE CO. LTD., TRANSMITTING & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

MVT20

Electronic Engineering

EDITORIAL, ADVERTISING AND PUBLISHING OFFICES, 28, ESSEX STREET, STRAND, W.C.2.

TELEPHONE: CENTRAL 6565 (10 LINES) *MANAGING EDITOR:* G. PARR, M.I.E.E. *TELEGRAMS:* LECTRONING, ESTRAND, LONDON

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Vol. 20. No. 241 March, 1948

CONTENTS

Service

UNDER the title: "Radio Repairs—Racket or Not?" a reporter on one of the Sunday papers has written of his experiences in having a receiver repaired at a number of dealers.* The price charged him for repairing a fault due to a wire deliberately broken off under the chassis varied from 11s. to 27s. 6d. In no case, says the reporter, was he informed that the wire had been deliberately disconnected, and he implies that the charge for repair by even the most reasonable dealer was excessive.

Mr. H. A. Curtis, Secretary of the Radio and Television Retailers' Association, has ably defended the retailer by pointing out what is common knowledge to the experienced radio serviceman—that a set cannot be repaired without a thorough test, first to determine the fault, and then to make sure that the repair is adequate.

It is Mr. Curtis' opinion that an average charge of 17s. 6d. for repairing a simple fault is not excessive, having regard to the time and skill involved, and most servicemen will agree with him.

(As to the reporter being kept in ignorance of the fault which he himself had produced, there is no reason for the dealer to suppose that he would be any wiser when he was told. If a watch will not go, does it help the owner to be told by the repairer that the pallets are too deep on the scape teeth?)

Nevertheless, there is sufficient justification in many cases to warrant hard things being said about the radio repair trade. Again quoting Mr. Curtis: "There is nothing to prevent anybody with or without experience, with or without equipment, and with or without conscience, to set up as a radio expert."

This is the condition which the industry is doing its best to remedy, handicapped by the absence of legislation which protects the public in other directions. No one can call himself a dental surgeon or a solicitor with impunity, yet the words "radio engineer" or "service engineer" are used or abused by many who have no shadow of claim to technical knowledge.

The increase in television receiver sales will aggravate the problem, and, as Mr. G. H. Watson suggests,† it might be good policy for manufacturers to limit their sales to dealers with personnel of recognised standing. One well-known manufacturer has already given a lead in this direction, and it is hoped that restrictions will be successfully imposed before television finds itself in the same plight as radio service.

It is too much to hope that the radio engineer will be protected in the same way as other professional men, but more can be done to educate the public into an appreciation of the difference between qualified and an unqualified service. For example, a label could be affixed to each receiver sold, recommending that it should be taken only to a qualified dealer for repair, the term "qualified dealer" being explained by propaganda in the press and in poster form. The bona fide dealer should be pleased to co-operate in a scheme which would ensure recognition of his status and discourage the dabbler and less scrupulous competitor.

* *Sunday Dispatch*, Feb. 15.
† Radio Section, I.E.E. Discussion, Feb. 14.

Modern Geiger-Müller Tubes

By O. J. RUSSELL, B.Sc.*

THE Geiger-Müller tube still largely retains its reputation of being a temperamental laboratory device. While it is certainly not an easy matter to produce robust and stable Geiger-Müller tubes of standardised characteristics, these are now produced commercially. Many tubes are, in fact, fitted with international octal bases, and uniformity is often such that a tube may be changed without necessitating any apparatus adjustment whatsoever. When it is considered that a G.M. tube is actuated by single atomic events, this is a combination of stability with sensitivity that is virtually unparalleled.

A brief recapitulation of the modes of operation of the Geiger-Müller ("G.M.") tube is all that can be given here, as this is adequately covered in the literature.[1,2,3] While various geometrical constructions are employed for specific purposes, the most generally employed electrode structure is that of a cylindrical cathode with an axially disposed wire anode. The tube filling consists usually of an inert elementary gas, with or without more complex gases—often organic. The complex gas added to the tube filling plays an important role in the discharge mechanism, and operates to quench the discharge initiated by an ionising event. Without some quenching mechanism the discharge, once initiated, would continue. Quenching may be effected wholly or partially by these appropriate circuit arrangements. It is therefore customary to classify G.M. tubes into internal and external extinction types, according to whether the discharge is quenched by the use of suitable gas mixtures, or if quenching is to be obtained by external circuit arrangements. However, this distinction is of types rather than of applications, as it is common practice to utilise internal extinction tubes in conjunction with external extinction circuits, as this often offers considerable practical advantages.

A crude but convenient analogue of the G.M. tube is the triode gas discharge tube. The G.M. tube, when a low potential is applied, behaves as a simple ionisation chamber. The pulse produced by the ionising event is dependent only upon the ionising ability of the

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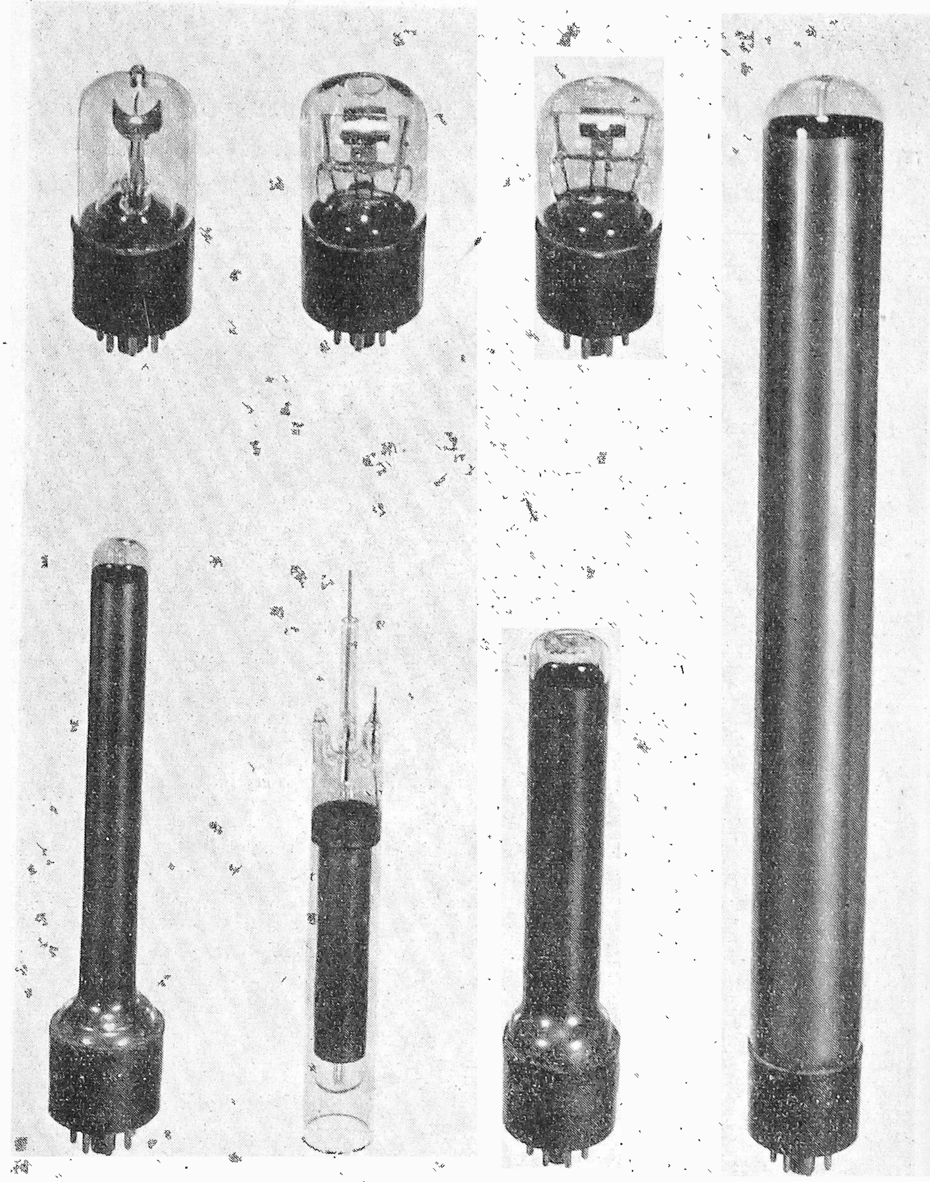

Typical Geiger-Müller tubes.

Type numbers, reading from left to right—

(Top row)

GT3 A small alpha particle and X-ray tube.

GT2 A small beta-ray tube.

GT1 A small gamma and cosmic ray tube.

(Bottom row)

GT11 A supersensitive beta-ray tube for isotope tracer work, especially with solutions.

MRC1 A beta-ray tube for medical, biological and other isotope tracer work, with a solution-holding skirt for 'radiological assays.'

GTX1 A special type for X-ray diffraction work, sensitive even to soft X-rays and to very low intensities of a few quanta per second.

GT21 A general purpose robust gamma and cosmic ray tube suitable for portable work.

vent. At increased values of the pplied potential, a measure of gas amplification" occurs, and ne pulses, while still proportional the ionising power of the ionising vent, become larger. As a matter f interest, amplifications up to 10^5 nay be obtained in the proportional egion, and with a moderate degree f additional amplification the ulses may be made to operate ecording devices, or be displayed on cathode ray tube—the pulse amplitude being proportional to the onising power of the event.

As the applied potential is increased still further, the proportionality falls off. While the bsolute value of amplification ncreases, it is relatively lower for trong ionising events than for weak onising events. With further increase in potential a point is reached hen all pulses, whatever the ionisng power of the event, are of the ame magnitude. This is the hreshold of the Geiger regime, and hroughout the Geiger region pulse ze still increases with applied tube otential. The limit of the Geiger egion with further tube potential ncreases is reached when the tube oes into a continuous discharge. hroughout the Geiger Region, owever, the pulse magnitude is ndependent of the ionising power of he ionising event.

For practical operation it is desirble that there should be a large oltage range above the threshold, ithin which stable operation can e obtained. It is this criterion hich should be applied in choosing tube for practical operation. Much aluable work has been done with nakeshift tubes with only a few olts of usable operating region. However, the wide expansion of the pplication of such tubes, especially or semi-industrial and industrial urposes, requires tubes insensitive o slight voltage changes, and enerally uncritical as to circuit arameters. The operating characeristics can be most conveniently etermined by testing in conjuncion with the circuit to be employed. f the voltage applied to the Geiger ube is slowly increased the countng section commences at a fairly harp limiting voltage, and increases apidly until the characteristic ounting rate for the tube deermined by the natural background f Cosmic radiation and other adiations that may be present, is eached. The threshold of usually bserved counting action is not

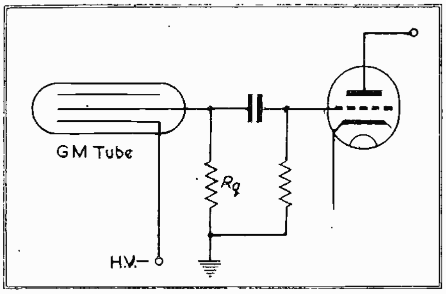

Fig. 1. Simple resistance quenching relying on voltage drop through R_q to quench discharge. R_q varies from 10^6 ohms to 10^9 ohms according to type of G.M. tube

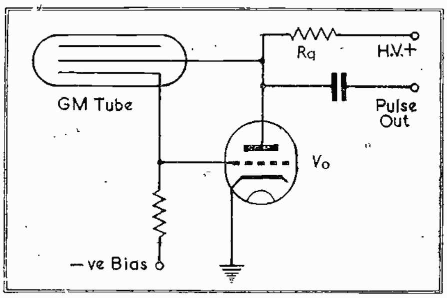

Fig. 2. Neher-Harper extinction circuit. V_o biased to cut-off, conducts when pulse from G.M. is applied to grid. This increases voltage drop through R_q, and extinguishes the tube

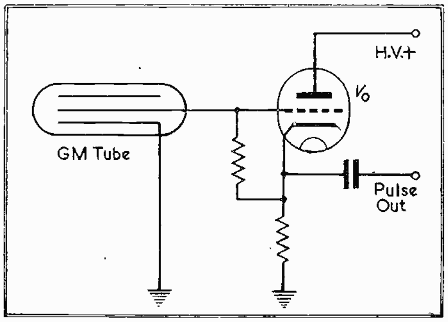

Fig. 3. Neher-Pickering extinction circuit. V_o normally conducting cuts off when G.M. tube fires, thus lowering the voltage and extinguishing the tube

necessarily the threshold of the Geiger region, as the counting device often requires a certain pulse level before operating, and in general the observed counting threshold has no fundamental significance. It is, of course, quite possible to count below the threshold of the Geiger regime, although pulse amplitudes will then be dependent upon the ionising powers of the ionising events. This mode of operation is often employed for certain applications.

The "Plateau"

Over a range of potential above the Geiger threshold the counting rate should be sensibly constant. This range is spoken of as the "plateau" for the tube. As the voltage is increased the limit of the plateau is reached, and a rapid increase in counting rate occurs as the tube approaches the condition of continuous spill-over. It is obvious that the range of the plateau is an important criterion of tube performance. It can be stated as a general guiding rule that a tube having a large plateau will tend also to have a flat plateau. Tubes having small and by no means flat plateaux are still common. A plateau measured in tens of volts with a high rate of change of counting rate is regarded in some quarters as satisfactory, and even as the normal characteristic of the G.M. tube. With modern technique, however, a plateau of two or three hundred volts, that is flat to within normal experimental error, is a routine manufacturing standard. It is undesirable for critical work to use tubes that require close control of applied voltage and circuit conditions for reproducible results. A tube with a limited plateau is, in fact, undesirable as this is usually an indication of the occurrence of spurious counts and hence of unreliability.

It is with tubes of such limited characteristics that circuits designed to suppress poor performance are applied. One typical arrangement consists of a multi-vibrator triggered by the discharge. As spurious discharges often occur immediately after a true discharge, by suitable choice of time constant the multivibrator can be in an insensitive state while the immediately following spurious discharge takes place. The effect is artificially to flatten the plateau, as the spurious secondary discharges no longer affect the multi-vibrator during the recovery period. The counting circuits operated from the multi-vibrator pulses do not record the close spaced G.M. tube spurious pulses following upon the true discharge pulse. The serious hysteresis and large temperature coefficient effects commonly present with such tubes are not necessarily affected. There is a danger with such arrangements that the anomalous behaviour of poor G.M. tubes may be concealed, and large errors could conceivably be introduced without their being suspected. The resolving power for fast counting rates is in any case reduced. It should be mentioned that circuits applying large reverse quenching pulses to the G.M. tube are also employed. These have the object of reducing the recovery time of the tube when dealing with extremely high counting rates. It should be realised that for normal quantitative purposes very high counting rates are not in general necessary or desirable. The recovery time of a G.M. tube itself being normally of the order of 10^{-3} to 10^{-4} second, the associated circuits are necessarily required to resolve to this limit at least, a not very stringent requirement.

Typical Performance

As an example of a typical plateau performance, a curve is given of actual figures taken on a medium sized "Alltools" Cosmic & Gamma type counter tube in conjunction with standard Geiger-Müller counter apparatus. This tube, far from being specially selected, has, in fact, been in continual service for years before the figures shown here were taken. Even so, the plateau is so flat that the statistical fluctuations of the random Cosmic ray background necessitate a long count (in this case ten minutes), in order to reduce normal statistical fluctuations to an extent in which any possible slope to the plateau can be detected. By chance, the actual deviation of the recorded counts within the plateau region are considerably less in this series of observations than the expected random fluctuations of the cosmic ray background. It is clear that even on a ten-minute count any voltage dependence of counting rate is negligible in comparison with the statistical fluctuation of the background. No apology is offered therefore for drawing the plateau as an accurate horizontal line, as the experimental points are shown.

The performance of such tube illustrates the reliability that can be obtained in precision work. With high performance tubes, a stability of counting of the order of 0.1 per cent. over long periods is obtained, without the use of special circuits. Thus points taken at eight-hour intervals for decay curve plots deviate by less than one part in 700 from the expected decay curve. The flat, wide plateau makes critical voltage control unnecessary, simplifying circuit arrangements. The very obvious stability engenders some considerable confidence in critical determinations dependent upon accurate measurements of

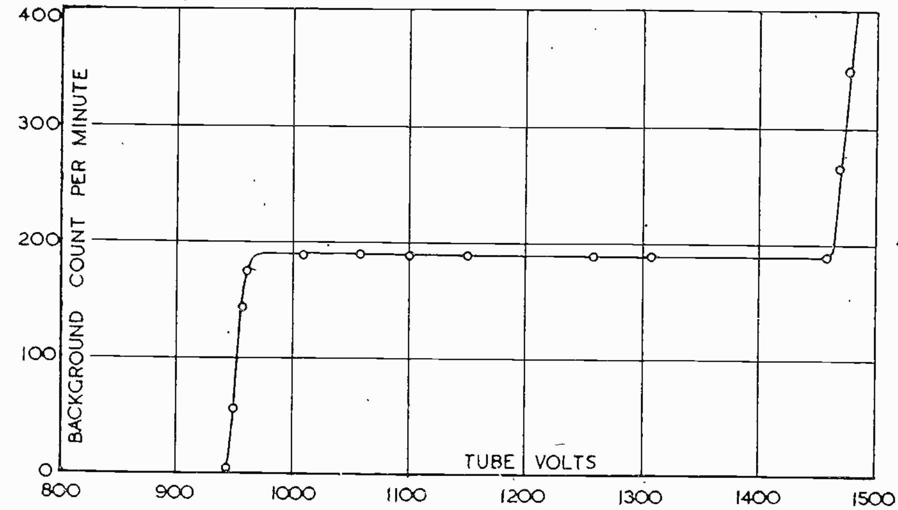

Fig. 4. Measured plateau characteristics of Geiger Müller-tube.

counts small compared with the background count rate.

It is perhaps as well to mention briefly the limitations imposed by the unavoidable presence of the background of cosmic radiation. This being a random series of ionising events, there will be a readily calculable probable deviation on any one determination of this background. This, of course, applies to any determination of similar random events, as for example, nuclear disintegrations.

As the background count is a statistical average, for a count averaging N, the probable error may be taken as P.E. $= 0.6745 \sqrt{N}$. The standard deviation $\sigma = \pm \sqrt{N}$ is a more convenient parameter and the square root of any total count of random events is a useful guide to the accuracy attainable in any determination.

On a one minute count, with an average value of 40, the standard deviation will be $\pm \sqrt{40} = 6.33$ counts or 15.9 per cent. If we now take a ten minute count, the average total count will be 400, and the standard deviation will be $\sqrt{400} = 20$ or 5 per cent.

For the case, as often happens, where we are interested in the detection of a feeble radiation level giving a very small count, it is necessary to ensure that the slight increase is greater than the likely statistical fluctuations in the background. The probability of fluctuations about the mean value can be exactly calculated. Thus values that have a fluctuation greater than five times the probable error occur less than once in a thousand times. As five times the probable error is approximately 3.37 times the standard deviation, we can conveniently take four times the standard deviation, i.e., $4\sqrt{N}$ as a variation from the mean that is significant with small chance of error. If results are duplicated, the reality of the significance of an increase of counting rate is higher still. Carrying the conclusions a step further, if N_o is the average background, and N_x is the average intensity of a source of radiation, then the combined count is $(N_o + N_x)$, and the standard deviation associated with this is

$$\sigma_1 = \pm \sqrt{(N_o + N_x)}.$$

The error associated with the background determination is

$$\sigma_o = \pm \sqrt{N_o}.$$

The radiation source count is $(N_o + N_x) - N_o = N_x$, but the standard deviation of the figure obtained by subtraction of the background reading from background plus radiation source, is

$$\sigma_x = \pm \sqrt{\sigma_1^2 + \sigma_2^2}.$$

The precise determination of counts small compared with the background is thus a lengthy process.

The present great interest in the development of isotope tracer technique, involving, as it does for biological applications, the minimum of material, throws the question of attainable precision into prominence. While tubes and equipment reliable to an order of a few per cent. are employed largely in this work, the gain in using modern tubes stable to the order of 0.1 per cent. is very real. It is desirable to stress that the statistical limits of precision are only attainable with apparatus of absolute accuracy. The errors due to unreliable apparatus, in particular tubes of doubtful performance, can be treated statistically, but as this is identical with the introduction of very large random errors into the determination, the calculation of errors on a simple statistical basis leads to a false confidence in the accuracy of the results. While this should be appreciated as an axiom, in practice it is readily overlooked. The confusion and errors likely in much preliminary isotope tracer work, render warnings on this score imperative.

Potassium Determination

As an example of work using tubes and equipment capable of long and reliable operation, we may take the determination of natural potassium. It is well known that the majority of radioactive isotopes of interest for tracer investigations are Beta-ray emitters, and their determination hinges upon accurate measurement of their Beta activity. Naturally occurring potassium contains a Beta-emitting isotope K_{40}, present in all normal potassium compounds to the extent of 0.012 per cent. This provides an interesting method of estimating natural potassium.

Employing a high sensitivity Beta-counter tube of stable design, with a cathode of six centimetres active length, the background count when unshielded in a laboratory of rather higher background than the normal cosmic ray background was found to be 39.6 per minute, with a standard deviation of $\pm$ 6.3 counts. Using 10 ml of a 10 per cent. W/V solution of KCl, i.e., approximately 0.5 gm of potassium element, an increase of 71 counts per minute was obtained.

To a good first approximation, taking the background as 40 per minute, and the activity of 1 gm. of KCl (0.5 gm. Potassium) as 70 counts per minute, on a ten minute background count, the total count is 400, and the standard deviation $\pm \sqrt{400} = 20$. This standard deviation of 20 corresponds therefore to a standard deviation of $\pm$ 2 counts per minute. From statistical reasoning, an increase of four times this, that is $\pm$ 8 counts per minute could be taken as a significant increase with a possibility of error less than one in a thousand. This corresponds roughly with the detection (rather than estimation) of 0.1 gms. of KCl (or 0.05 gm.) of potassium under the conditions of the quoted experiment. By taking a longer count, say, 100 minutes, this concentration could be estimated with fair accuracy, in fact, approximately 10 per cent. Where the expected increase is only a small fraction of the background count, it is sufficiently accurate for many purposes to take the standard deviation of the background as the deviation of the quantity being measured.

The necessity for tubes capable of operating reliably and stably for long periods is at once apparent, for in general an N-fold increase in precision of a given determination requires an N^2-fold increase in counting time.

The above consideration of the estimation of potassium shows that under the conditions of the original experiment 0.05 gm. of potassium, that is 10 ml. of 1 per cent. KCl solution can be estimated. As it is not necessary to effect a complete chemical separation, the count time of 100 minutes compares very favourably with chemical determinations. The conditions by no means represent ideal conditions as with a moderate degree of shielding, such as may be readily provided by two to three inches of lead, to remove the less penetrating components of the cosmic radiation, the background count may be at least halved. Further, owing to the marked absorption of Beta-radiation in the aqueous solution, a much thinner film of liquid surrounding the tube may be used without greatly reducing the count. By this means, the sensitivity for small quantities of potassium may be enhanced. It is found possible to determine in practice concentrations of the order of 0.3 per cent. of potassium to $\pm$ 10 per cent. conveniently. Spectrographic potassium determinations are, of course, much more sensitive, but have the disadvantage that their precision is low, and is not appreciably increased at high concentrations. The radioactivity method of determination increases in precision with concentration, and offers some special advantages over chemical methods of determination.

Special Types

The above consideration of the statistical limitations applying to isotope detection serves to stress the necessity for absolute reliability and uniformity if the full capabilities of Geiger-Müller tubes are to be realised. While it is of the first importance that a G.M. tube should have stable characteristics, it is of some importance that tubes should also be uniform in characteristics among themselves. The controls employed to produce stable tubes can confidently be expected also to produce reasonably uniform tubes. A test of a group of G.T. 11 thin-walled Beta Counter tubes, from differing production batches, gave a statistical standard deviation of average background counts of 5 per cent., which is highly satisfactory.

The tendency of the modern G.M. tube design towards uniformity and reliability has been coupled with the production of a large number of specialised types for specific applications. In the smaller sizes, where it is practicable, these are provided with international octal bases for rapid interchangeability with standard G.M. counter equipment. Some of these types are shown on p. 70. They fall into four groups. Those specifically designed for use as counters for alpha particles provided with extremely thin film windows; those designed for Beta ray counting, with thin walls; X-ray types for spectrum analysis and scanning technique material inspections, etc., and finally, counter tubes for gamma and cosmic radiation. The tube lengths vary from small two-inch bulb low background tubes, up to tubes five feet in length designed for stray radiation monitoring purposes. In addition multiple and other special types for specific applications are produced. It should be noted, however, that tubes designed for special purposes are often equally serviceable for other applications. With regard to service life, it is of interest to note that the provision of stable and uniform tubes also ensures a very long useful life. A tube life of the order of 10^{12} counts is by no means exceptional, representing several years' service at a counting rate of a thousand a second. It is perhaps necessary to record that the tubes illustrated and discussed are entirely of British evolution, design and manufacture.

Thanks are expressed for the kind permission of the directors of Messrs. Alltools Ltd., to publish the above article, and accompanying illustrations.

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A New Electro-Acoustic Transducer

Operating with Short Pulses

By G. BRADFIELD, B.Sc.*

BOTH magneto - striction and piezo-electric electro - acoustic transducers have in the past mainly been used for generating continuous waves or damped trains of oscillations. For either of these types of oscillation, the acoustic wave could be considered as traversing and re-traversing a path of limited length in the transducer, losing part of its energy into the acoustic load at each encounter with the loaded interface. The method of wave generation in the devices now to be described differs from this because the wave originates in a location remote from the ends of the magneto-strictive or piezo-electric body in which it is propagated. This method of generation inevitably gives rise to two waves moving in opposite directions. By permitting one wave to propagate freely in the generator body while the other is being launched from the end of the body, this latter wave can be used for exploration without interference from the former.

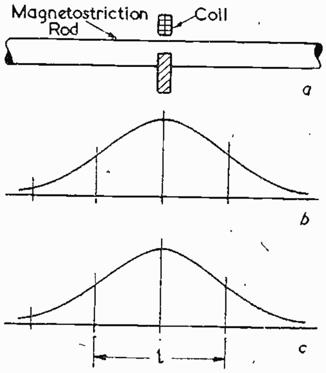

Fig. 1. Wave generated in magneto-striction rod

Methods of generation of such waves are illustrated in Figs. 1 and 2 for the cases of generation in magneto-strictive and piezo-electric media respectively. In Fig. 1a there is a short coil embracing a rod of the magneto-strictive material and when current is passed through this coil the flux density varies along the rod as shown in Fig. 1b. According to the characteristics of magneto-striction materials a strain is set up in the body of the material which, in the steady state, would be as shown in Fig. 1c. Immediately this condition is set up the wave travels simultaneously to the left and right with a velocity c where:

$$c = \sqrt{\frac{E}{\rho}} \quad \text{(1)}$$

E being the Young's Modulus of the material of the rod and ρ its density. An exactly similar state of affairs occurs in the case of the piezo-electric generator of the type shown in Fig. 2, where application

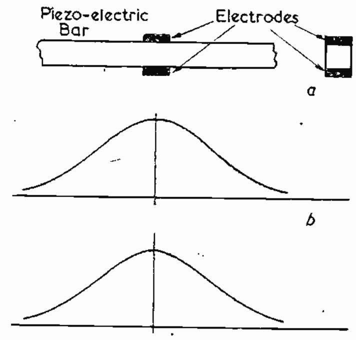

Fig. 2. Wave generated in piezo-electric bar. 45° X-cut Rochelle salt transducer

of a potential difference to the pair of electrodes causes a field intensity which falls off with the distance from the centre of the electrodes as in Fig. 2b in a very similar manner to Fig. 1b. This causes a strain in the piezo-electric material as in Fig. 2c for the static case.

These waves travel freely along a rod of magneto-striction material and can, indeed, travel for considerable distances substantially in the original form of Fig. 1c, or 2c. If a rod of nickel is polarised over a short length and a short coil embraces this length, when the travelling strain wave reaches the coil, the permeability of the material is changed, thus, for the polarised stretch, changing the flux linking the coil.

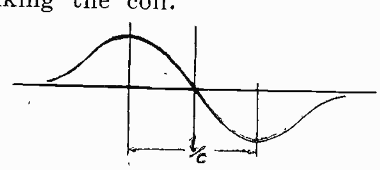

Fig. 3. Voltage wave from nickel rod

The flux changes with time with a curve similar to that of Fig. 1c. The resulting voltage wave on the coil is thus the differential of such a curve, as shown in Fig. 3.

In the case of the piezo-electric device the resulting charge on the electrodes will vary with time according to the curve of Fig. 2c, and the curve of voltage against time on a light load will be of similar shape.

A wave of the form shown in Fig. 3b has rather a wide frequency spectrum which is roughly of the form shown in Fig. 4. The frequency of maximum energy has a value c/l; where l is the length between maxima on Fig. 3, and c is given in Equation 1.

It has been found, in the case of the generation of these waves in a rod of nickel, that the length l is about ten diameters of the rod so that this is the wavelength of the main frequency in the rod. A considerable proportion of the total energy is, however, present on higher frequencies. The wideness of the frequency spectrum can result in dispersion

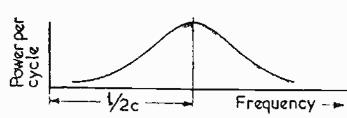

Fig. 4. Frequency spectrum of wave of Fig. 3

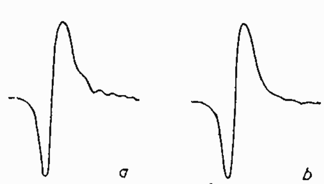

Fig. 5. Degeneration of wave-form of Fig. 3 by phase-shift of the harmonics. (b) shows less shift than (a)

phenomena, because the velocity varies with the wavelength when the latter is of the same order as the rod diameter. For the 5th or 10 harmonic the wavelength is only 1 or 2 diameters and accordingly the velocity of propagation is considerably slower than when a

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wavelength as many as ten times the rod diameter is being propagated. This progressively delays the high frequency components of the wave and they become more and more out of phase with the lower frequency components. As will be evident from oscillograms below, degeneration of the simple waveform of Fig. 3 occurs and results in a wave as sketched in Fig. 5.

Apparatus for Generating and Demonstrating Short Waves

One of the simplest pieces of apparatus for generating these waves is the magneto-striction device shown in the photograph of Fig. 6. A close-up of the polarised section of the rod with its pick-up coil is shown in Fig. 7. It is not essential to use polarisation in the case of the transmitting coil as a unidirectional current pulse can be employed. The rod used is made of nickel, $\frac{1}{4}$ in. diameter and about 3 ft. long.

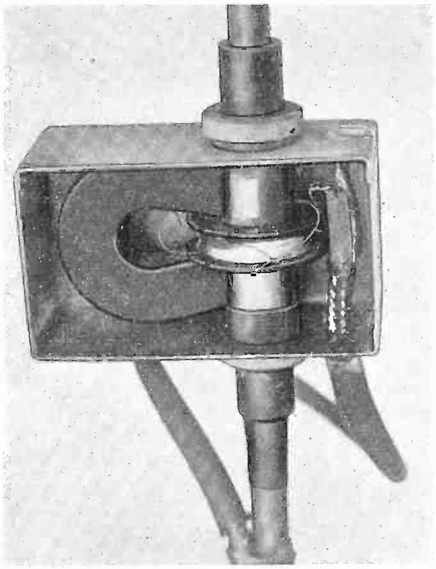


Fig. 7. Close-up of the interior of the receiver coil box showing permanent magnet (*left*), iron pole pieces, and bobbin-wound coil

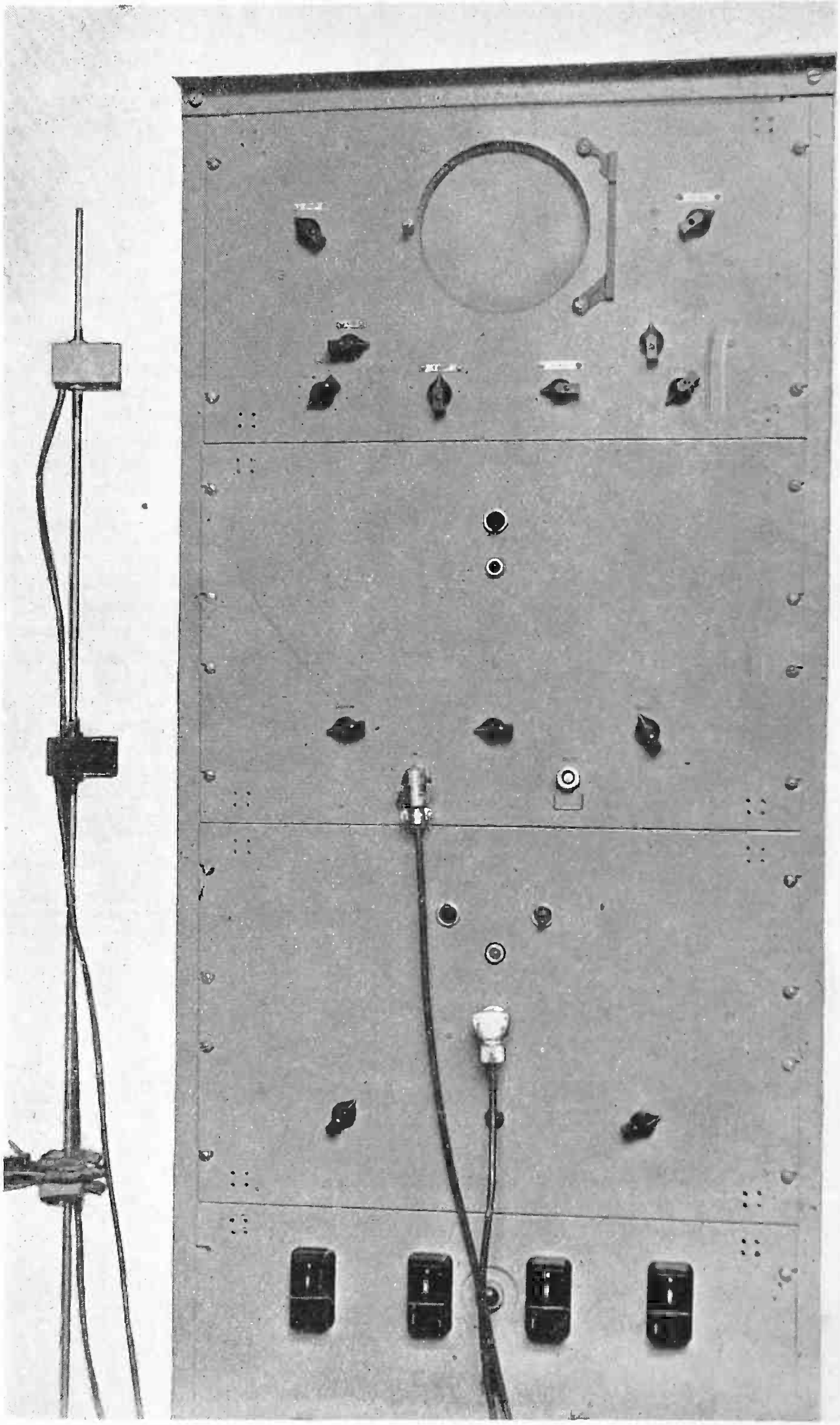
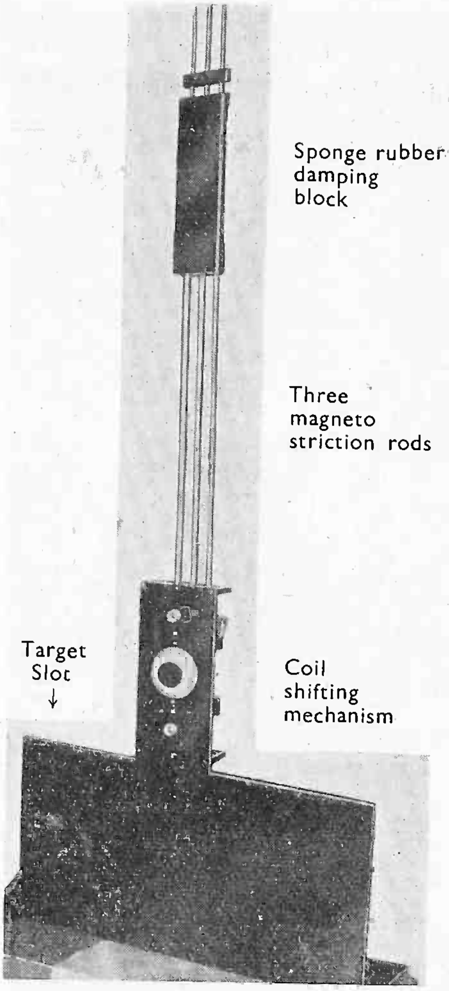


Fig. 6. Magneto-striction device and display equipment. The rod is shown on the left, with the pickup coil in a screening box near the top. The transmitter coil is further down the rod

It is possible to generate waves of a similar type in three separate rods and launch these into a body with suitable phase relationships so as to give greatest augmentation in a certain direction. This principle can be demonstrated by the equipment shown in Figs. 8 and 9.

Use of Apparatus

The simple equipment as in Fig. 6 permits some interesting experiments to be performed. At the top end of a rod, another rod of any desired material can be supplied, in general a thin film of vaseline being added to avoid the presence of an air film and so give better acoustic contact. Some of the acoustic energy is reflected at the contact

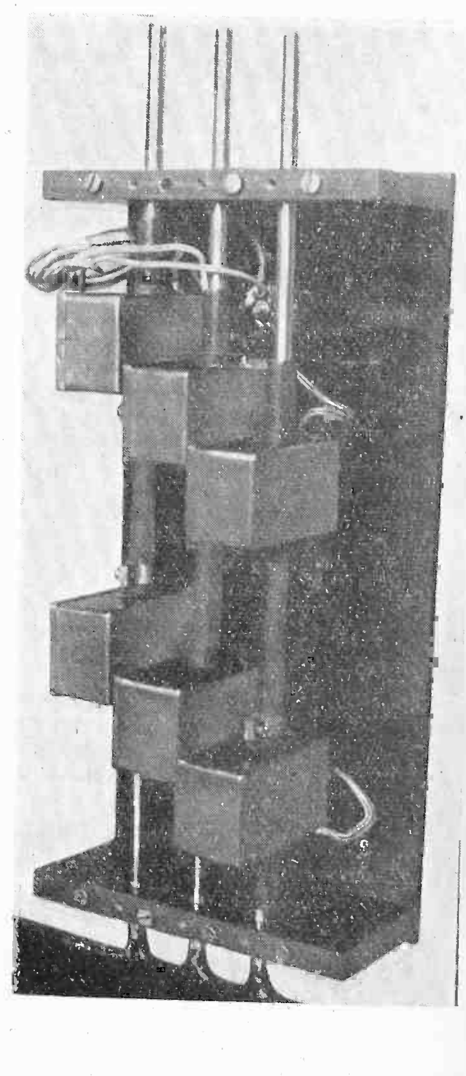


face because there is never a perfect match between the two media. The energy which succeeds in passing through the interface travels in the new medium and is then reflected from the upper end of the test piece to travel down towards the generator again. When it meets the interface between the magneto-striction rod and the test piece partial reflexion and partial transmission again occurs and the transmitted wave travels down to reveal its presence in the pick-up coil on the magneto-striction rod while the wave reflected at the interface after its downward travel returns up the test piece again to repeat the cycle just described. The result is a succession of reflected waves re-entering the magneto-striction generator and being revealed during their passage through the pick-up coil. The waveforms obtained in the operation of the apparatus are of considerable interest and some are shown in Fig. 10. Fig. 10a represents the normal operation of the apparatus and Fig. 10b shows what happens when the coils are moved so as to increase the length of rod between the transmitter and the pick-up coils. The second wave A2 in Fig. 10a represents the reflexion of the energy from the end of the magneto-striction rod in the absence of a test piece, while on the left hand the wave A1 has only traversed the distance between the transmitter and the pick-up coils. The phase change of the reflected wave should be noted and also the way in which the increased path has started to introduce degeneration of the waveform owing to appearance of the higher frequencies out of phase. That this is a matter of path length can be clearly seen in Fig. 10b where the total distance traversed for the reflected wave is the same as the total distance traversed for the direct wave in Fig. 10a. These two waves have suffered a similar amount of degeneration, while the waves traversing a longer path length are more seriously degenerated. (See also Fig. 11c.) The velocity in the test pieces can readily be deduced from the distance between successive peaks and this is an elegant method of measuring velocity in various materials

Fig. 8. Steerable sonic beam

Fig. 9. (*right*) Close-up of rear of coil-shifting mechanism

Fig. 10. (*below*) Oscillograms of the waveforms obtained by the apparatus of Fig. 6



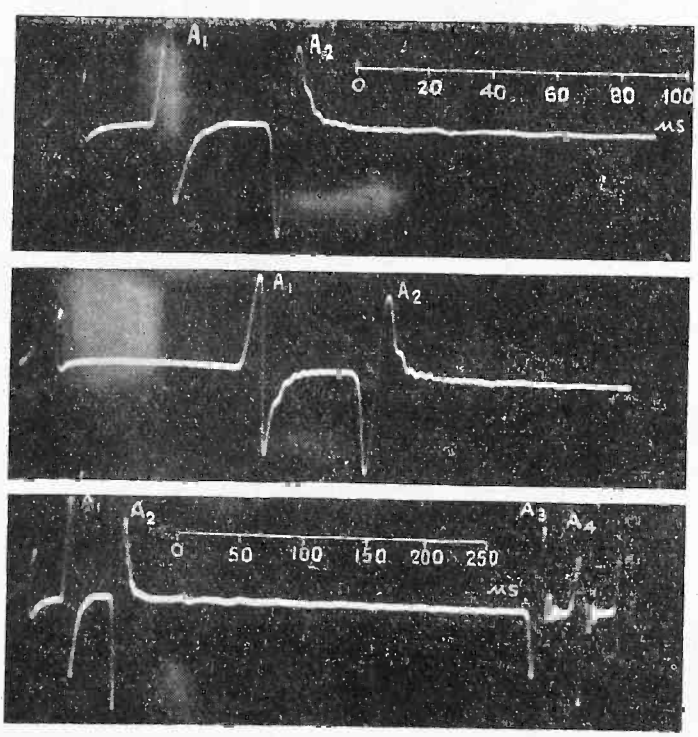


Fig. 10. (a) Normal operation showing direct wave and first reflexion No test object

(b) As Fig. 10a but transmitter coil moved further from pick-up coil. No test object

(c) As Fig. 10a but on slower time base. A3 and A4 are waves reflected from lower end of rod. No test object even with short test pieces. Fig. 11a, b and c represent oscillograms for a short length of bakelite, in a steel rod, and in a length of nickel steel rod respectively. In the case of the nickel steel rod, the rod itself has been cut obliquely and smoothed and brazed to make a very neat joint, but in spite of this, reflexion takes place at the joint as shown by the wave at x in Fig. 11c.

The test piece or the main rod itself can be modified by mounting diaphragms on the rod, (which, incidentally, cause very little irregularity in the rod), by tapering the rod to a point, by stressing the rod locally or by clamping the rod in a damping material such as sponge rubber. Much useful information concerning acoustic couplings and propagation can be obtained thereby in a simple manner.

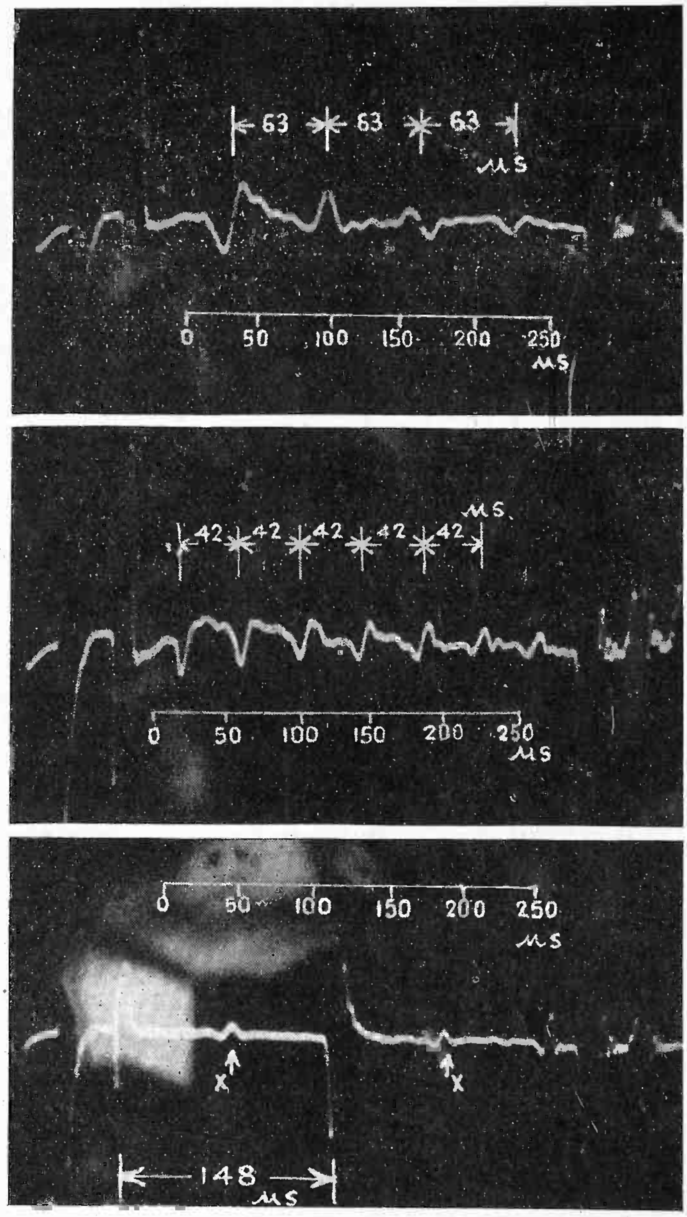


Fig. 11. Oscillograms of various test pieces.

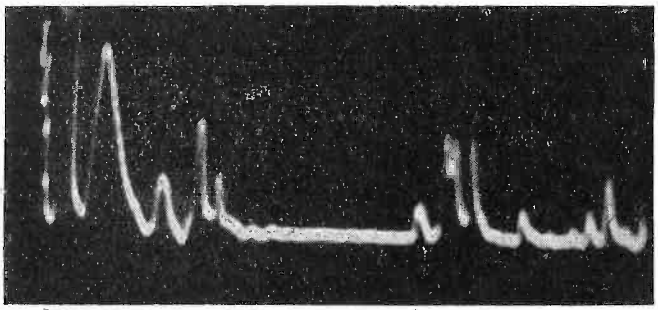
Bakelite test piece, 10.3 cms × 1.55 cms dia. Velocity of Supersonic waves = 3300 m/sec

Steel Test Piece 11.3 cms × 1.25 cms dia. Velocity of supersonic waves=5400 m/sec

Spliced nickel steel test piece, 37.2 cms×.62 cms dia. Velocity of supersonic waves=5040 m/sec

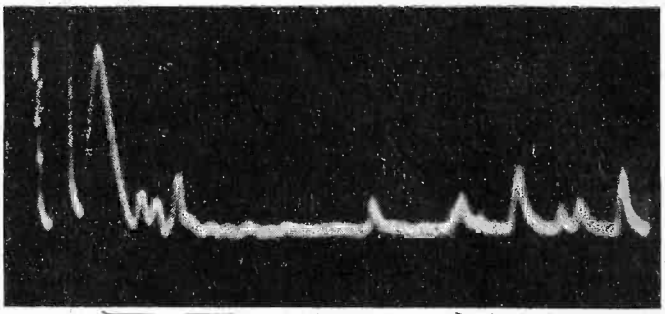
"Steerable Beam"

The operation of the equipment called "steerable beam device," shown in Figs. 8 and 9, is as follows. The rods each carry a transmitter coal and a receiver coil, at a fixed distance apart, as an assembly which can slide on the rod so that the relative phasing of the waves in the three rods can be adjusted. Each of the waves in the rods, which are about 10 or 12 microseconds long, arise from the same current pulse, the three coils being connected in series. In a similar way the received pulses in the pick-up coils are added and the combined pick-up is displayed on the screen of a cathode-ray tube against time elapsing after the start of the transmitted current pulse. When the coils are arranged so that all the pulses leave the ends of the rods in phase a strong reflexion is obtained from the opposite side of the plate 12 in. away. This is shown in Fig. 12a.



Transmitted pulse — Reflexion from the opposite side of the plate

Fig. 12a



Transmitted pulse — Reflexion from slot target

Fig. 12b

On moving the coils, which is done mechanically by a knob controlled gear so as to retard one pulse in, say, the left-hand rod with respect to the pulse in the centre rod, and advance the pulse in the right-hand rod by a corresponding amount with respect to the pulse in the centre rod, the echo from the opposite side decreases and "spreads," while that from the slot target increases in amplitude as is shown in Fig. 12b. This echo becomes a maximum when the coils are in a position such that the three waves encounter the slot simultaneously. The signals displayed have been rectified in order to simplify the picture. The "bearing" of, for instance, the slot target found by experiment corresponds closely with that calculated from a knowledge of the separation of the ends of the rod generators, the velocity of the pulse in the iron plate and the relative time delays of the pulses in the generator rods.

Practical Application of the Principle

Only a little has been done up to the present to apply the above described waves practically, although the possibilities seem great. One example which has just recently been tried is a piece of equipment which can be applied to concrete slabs and which will enable a reflexion from the lower surface of the slab to be obtained to give an indication of the thickness of the slab. The first experimental equipment of this type is shown in Fig. 13 and consists of a ½ in. square laminated nickel rod, 2 ft. 6 in. long with the upper end encased in sponge rubber and the usual transmitter and pick-up coils. This shows echoes in slabs 1 in. and 2 in. thick and it is hoped that later designs will improve on this range. There appears to be a fair possibility that the magnitude of the reflected signal would reveal whether the concrete slab had an air cavity under it or was resting firmly on the sub-soil.

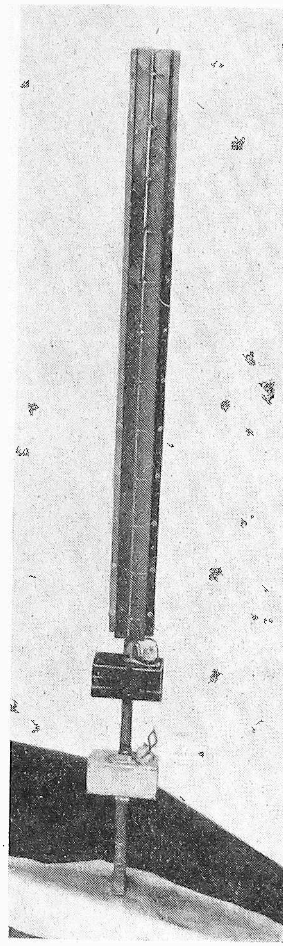


Fig. 13. Transmission and reflexion of short pulses in concrete slab

Piezo-electric crystal generators of this type have been tried and have given very short wavelengths which should be suitable for search for flaw detection in metals.

Acknowledgments

The author wishes to express his appreciation of the assistance he received in the design and building of this equipment from his colleagues at the Telecommunications Research Establishment, in particular from Mr. E. W. Pulsford, and to express his thanks to the Ministry of Supply for permission to publish the paper. (Crown copyright reserved. Reproduced with the permission of the Controller of H.M. Stationery Office).

PERMEABILITY TUNING COILS

PERMEABILITY tuning coils of the kind in which the coil is mounted on a tubular former containing an axially displaceable ferro-magnetic particle core are commonly used in radio receivers for tuning radio frequency and other circuits to resonance. Usually a cylindrical core is mounted on the end of a screw-threaded brass rod which projects through a screw-threaded aperture in the chassis or other part of the receiver and the core itself fits loosely in the coil former so that, in general, there is considerable lateral play and it is difficult to obtain precise adjustments.

This difficulty can be overcome by using a core with a cylindrical bore and slidingly mounting it upon a fixed rod of suitable size co-axial with the coil.

The rod may also be used to form one element of a variable condenser adjustable simultaneously with the adjustment of the coil and an arrangement of this kind is shown in the accompanying Figs. 1 and 2. Fig. 1 shows in section a side view of the coil and Fig. 2 an end view.

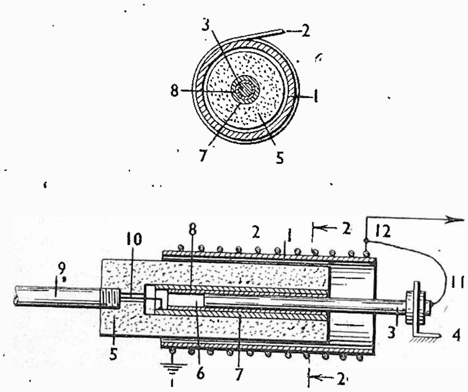


Fig. 1 (*top*). End view, and Fig. 2 (*below*). Side view of coil

1 is the coil former, 2 the coil winding and 3 the co-axial rod held by a rubber grummet on the mounting bracket 4. 5 is the high frequency core formed with a cylindrical bore 6 and mounted on the end of the adjustment rod 9.

The bore 6 of the core 5 is lined with a metal sleeve 7 forming the adjustable element of the condenser, this element being separated from the stationary element of the condenser, *i.e.*, rod 3, by a thin sleeve 8 of insulating material. A coating of ceramic may be applied to either the inner surface of the sleeve 7 or to the rod 3 to form the insulating sleeve.

By providing a close fit between the rod 3 and the insulating sleeve 7, lateral play is avoided and precise adjustments are possible.

The condensers may be shunted across the coil winding 2, by connecting the rod 3 by lead 11 to terminal 12 on the coil and by connecting sleeve 8 to the earthed end of the coil, via lead 10 and earthed adjusting rod 9. — *Electrical & Musical Industries, Ltd.*

High Vacuum Pumps

Their History and Development

By R. NEUMANN, Dipl. Ing., A.M.I.Mech.E.

Part 3 — Diffusion Pumps

As may be safely stated, the diffusion pump is now the one most commonly accepted for very high vacuum work in laboratory, research and industrial applications and an enormous number of articles in physical, chemical and technical journals as well as a very extensive patent literature have appeared since its invention by Gaede in 1913.

Its principle will perhaps best be understood by quoting from Gaede's first patent,[66] although the drawing shows a design (Fig. 17) which since then has been replaced by much more efficient ones. A quantity of mercury is contained in the lower part of a tube heated from outside at its bottom and connected at its top to the vessel to be evacuated. In the upper part of the tube a steel cylinder closed at its top and fitted with a slit is supported by a circular trough. The outer wall of the tube opposite the steel cylinder is water-cooled. A tube of small diameter concentric with the steel cylinder communicates with the mercury sump and with the fore-pump and carries also a water-cooled jacket.

The slit in the steel cylinder forms a "diffusion diaphragm," the width of the slit being of the order of magnitude of the mean free path of the molecules. When mercury vapour passes the slit, gas molecules, diffusing from outside the steel cylinder into the Hg vapour stream, are carried away to the fore-pump. Vapour molecules, diffusing in the opposite direction, are condensed and flow back to the Hg boiler.

This explanation appears to be simple enough although it may not give the whole picture. The phenomena are somewhat complicated and even quite recently it has been stated[67] that "quite a considerable amount remains to be done before the full theory of operation is understood."

The complication became first apparent when shortly after Gaede's first publication Langmuir published his ideas and a modified design of a high vacuum pump which did away with the narrow slit used by Gaede and replaced it by the opening

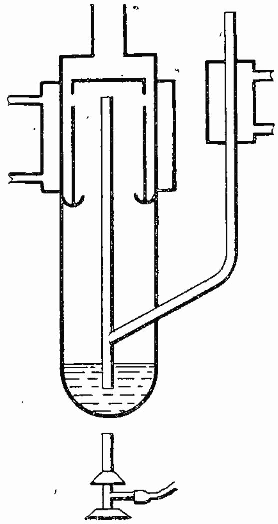


Fig. 17. Gaede's first diffusion pump

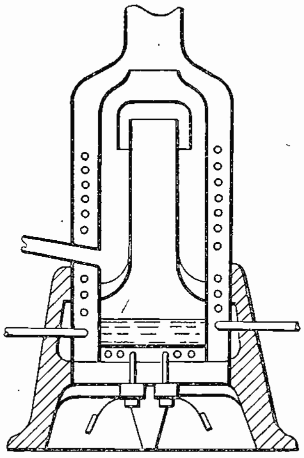


Fig. 18 Langmuir's metal diffusion pump ("umbrella type")

between the mouth of the nozzle and the condensing wall, the so-called throat. The new train of thoughts was influenced by his previous investigations on the surface effects encountered in the blackening of the bulbs of incandescent lamps. In his opinion the diffusion effect was of smaller importance than the condensation effect which prevented the Hg molecules from being scattered in all directions when striking the wall of the outer vessel, and thus impeding the rapid transport of the gas molecules from the recipient to the fore-vacuum. He therefore called his pump a condensation pump and it is still frequently called so in U.S.A., although of late the name diffusion pump is used there too to some extent.

In fact, Gaede's and Langmuir's pumps are based on diffusion as well as on condensation. Gaede himself, though not approving of Langmuir's explanation, admits that Langmuir's design brought a marked improvement in raising the suction speed attainable in the ratio of about 50 : 1, and in his later designs he abandoned the narrow slit and adopted the "umbrella type" as first shown in Langmuir's publications and patent (Fig. 18),[68] as well as his increased speed of Hg vapour flow. It is interesting to note that according to Gaede a simple water jet pump may be used for evacuating an X-ray tube if a diaphragm is interposed between the pump and the tube and thus the diffusion principle is applied. But the action is very slow.

As the opinion was frequently expressed that both the Gaede and Langmuir pumps were actually based on the Bernoulli effect (which forms the basis of the ejector principle) both inventors and others showed how and why this principle is not effective at the very low pressures at which diffusion or condensation pumps are called to work. Molthan[69] based his investigation on a calculation of the dispersal of the flow lines according to Maxwell's distribution of molecular speeds. With the comparatively low speed with which the vapour emerges from the nozzle of an ejector, eddies are formed by the flow lines and the air molecules enter these eddies and are carried away. In the high speed jet of the diffusion pump a small amount of vapour molecules leaving the nozzle move in counterdirection to the general, *e.g.*, downward, flow of vapour. The air molecules fly through these thin rising molecular swarms of the vapour bunch as the mean free path in this rising part of the stream bunch is large. Thus they are carried through into the part of the stream bunch flowing downwards. Here the mean free path is so small that the air and vapour molecules are pulled down by the vapour stream and led to the fore-vacuum. If the free path of the air molecules in the rising part of the vapour bunch is small compared with the width of the opening then the air molecules collide so frequently with the vapour molecules in the upper part of the bunch that practically all air is pushed back by the vapour. Thus, diffusion stops and the pump fails to work. This may be the case if the pressure in the fore-vacuum is too high or if the heating of the Hg is excessive. With sufficiently small pressure in the fore-vacuum the vapour may be adjusted between wide limits by adjusting the heating.[70]

The "historic controversy" between Gaede's and Langmuir's theories in explaining the working of the vapour stream pump has quite recently been discussed by P. Alexander.[71] His aim was to extend the working range of the pressures obtainable by Hg vapour pumps and to attain with these pumps similar high suction speeds which have been obtained by modern oil diffusion pumps. His theoretical considerations are based on Maxwell's molecular speed distribution and he brings experimental evidence based, on the one hand, on measuring the mass of Hg passing though the nozzle in unit time, and, on the other hand, on the spreading of metal vapour with high streaming velocities on glass sheets placed in different direction into the vapour stream. He concludes that the diffusion principle cannot explain the working of the Hg vapour pump sufficiently and that Langmuir's theory is preferable. Further experiments by which isobars in the space between the nozzle and the back-pressure outlet could be determined resulted in an improved design of the pump. It is characterised by an adjustable nozzle and adjustable throat, cooling of the pumping chambers, both from inside and outside, and by diminishing the diameter of the outer wall of the pumping chamber in the direction of vapour flow.

The design is somewhat complicated and further experience must show whether the good performance of the pump (1,000-1,500 l/sec. at pressures between 10^{-4} and 10^{-2} mm. Hg) justifies its wider application. Witty[67] attributes the difference between the Gaede and the Langmuir pump mainly to the difference in the so-called Ho-coefficient which is defined as the ratio between the actual speed of the pump and the conductance of the annular gap, *i.e.*, the ideal maximum speed.[72]

In a paper read in November, 1947, before the Physical Society D. G. Avery and R. Witty made a critical survey on the work of Gaede, Langmuir and Crawford in connexion with diffusion pumps. In their opinion the theory is best explained in Gaede's paper of 1923. Two processes are involved: the reduction of the backstreaming of the gas molecules and the removal of the gas to the backing side. The second process is accomplished in all three designs in a similar manner with final condensation of the vapours. For the first process Gaede adjusts temperature and vapour pressure, Langmuir designs his pump so that a vapour molecule would have to turn 180° if it was to flow contrary to the pumping direction, and Crawford increases the velocity of the vapour stream by a special shape of the jet (see below). All the three methods are usually applied in modern pumps.[72a]

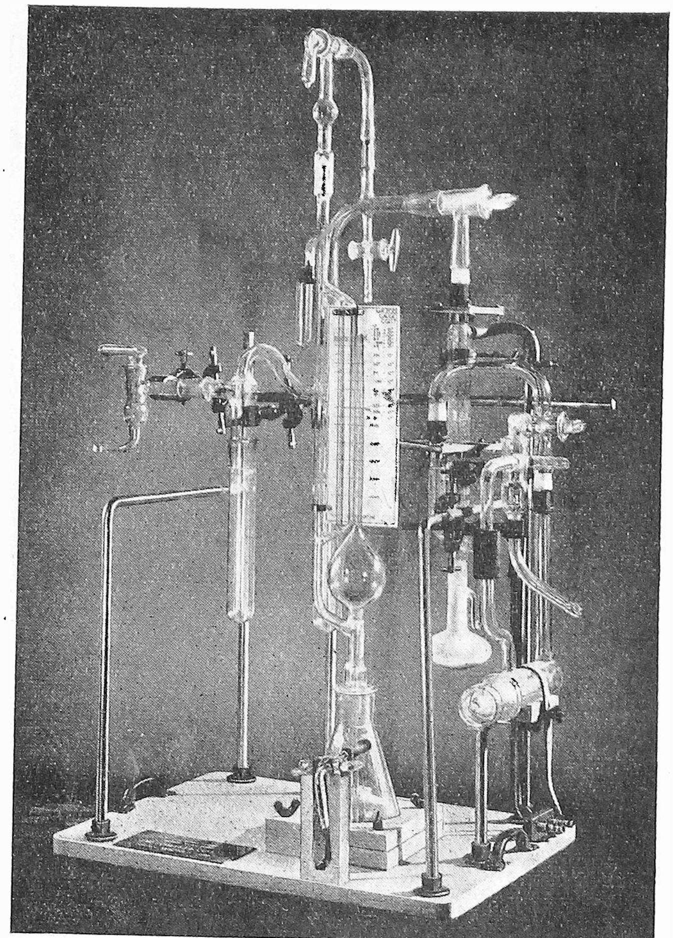


Fig. 19. Gilson's quartz diffusion pump (Towers)

Materials used for Pump and Working Fluid

Generally speaking, for the apparatus proper glass, quartz or metal, especially steel, are used as constructional materials.

Glass has the advantage that faults may be easily noticed. The glass pump may be readily fused to the rest of the glass system and it is therefore frequently preferred in laboratory work. The heat-resisting quality of Pyrex glass makes it especially suitable for pump design.[73] Quartz is sometimes used as it does not break so easily, especially on heating to higher temperatures. As an example may be mentioned the pumping unit designed for general laboratory use by A. R. Gilson and sold by J. W. Towers & Co., Ltd., Widnes (Fig. 19).[74] The unit contains a quartz three-stage mercury diffusion pump of robust design. Other examples are the "Vitreosil" pumps manufactured by The Thermal Syndicate, Ltd., Wallsend. They are umbrella type jet pumps achieving pressures of 2×10^{-6} mm. Hg with a backing pressure below 1 mm. Hg. The speeds are 0.4 l/sec. for the single stage, and 0.55 l/sec. for the two-stage design measured at 10 mm. Hg. Steel has the great advantage of being unbreakable and is therefore most widely used in laboratory as well as in industrial work where rough handling cannot be avoided. In some cases also combinations of the different materials are used. Thus, for instance, in one design[75] the boiler and the adjacent tube was made of metal or quartz and the diffuser and cooler of glass, or, in a diffusion pump otherwise consisting of metal, the leader, *i.e.*, the tube conveying the Hg from the boiler to the nozzle, was made of porcelain, earthenware, fireclay, quartz or glass.[76] According to Pilon,[77] quicker starting of the pump is attained by making the leader of aluminium and this, as well as the deflector or cowl, is nickel- or chromium-plated and highly-polished in order to decrease heat losses by radiation. Special kinds of surface treatment are also recommended for minimising the quantity of gas evolved from surfaces exposed to the vacuum.[78]

According to Klumb,[79] organic pump oils may corrode steel, copper and brass at higher temperatures and he recommends therefore the use of aluminium, tin, chromium or lead for the metal parts or their plating with one of these metals at those places where they are in contact with the pump fluid or vapour.

Another combined glass and metal design is used in Estermann and Byck's pump,[80] in which the umbrella type nozzle is made of metal and all the rest of Pyrex glass. This ensures the necessary accuracy of dimensions and spacing of the nozzle parts. Monel metal, stainless steel, brass or nickel are used for the metal parts if butylphthalate is used as working fluid.

In general it may be said that for small laboratory work the glass or quartz type pumps and for larger laboratory and industrial work the steel pump are most commonly used. The glass type pump is frequently made by the laboratory's own glassblower.

Within the first 15 years of the development of the diffusion pump mercury was exclusively used as working fluid and it is still used to a very large extent. The preference given to Hg over any other liquid that could have been used was mainly due to the previous association of Hg with air pumps, to its vapour pressure for many purposes sufficiently low, and to its chemical stability and non-wetting property. But mercury has also some disadvantages. Its vapour may be objectionable, *e.g.*, for hygienic reasons. Its vapour pressure is about 10^{-3} mm. Hg at room temperature and if lower total pressures are required special cold traps must be applied. The partial pressure of air may be as small as 10^{-6} mm. Hg even without cold trap. If heavy grease is used for tightening joints in the system a film of this grease deposited on the mercury may impair the performance of the pump.[81]

Low Vapour Pressure Oils

A very important step for the development of other working fluids was made when Burch[82] at the Metropolitan-Vickers research laboratory applied the method of molecular distillation to the fractionation of residues from petroleum refineries. Molecular distillation had been used by Brönsted and Hevesy of Copenhagen for separating the isotopes of mercury.[83] Even earlier applications may be found in Detwiler's bibliographies and a survey of the whole field of molecular distillation was published by Hickman.[84] The method differs from the usual methods of vacuum distillation in that a high vacuum is used sufficient to give an appreciable mean free path to the molecules, and that the distance separating the evaporating and condensing surfaces is less than the mean free path. Thus a large number of vaporised molecules travel directly to the condensing surface without collision with residual gas molecules or other vapour molecules. The temperature of vaporisation can be kept so low that decomposition (cracking) of the distillant is prevented.

In Burch's investigations the first product of interest in vacuum technique was a substance "not unlike common vacuum grease," the vacuum pressure of which was established by Cockcroft at the Cavendish Laboratory to be less than 0.75×10^{-6} mm. Hg. But also important less viscous substances were produced. "The fact that oils exist which can be distilled without decomposition and which have vapour pressures as low as 1 microbar at 100° C. suggested that it should be possible to run a condensation pump on an oil with a vapour pressure at room temperature negligible compared with that of mercury, and thus to obtain vacua of perhaps 10^{-3} microbars without using a liquid air or carbon dioxide snow trap." Tests with the evacuation of a low power transmitting triode showed that actually a fine pressure of less than 1.5×10^{-6} mm. Hg could be obtained. Even lower pressures could be established if the glassware was ovened and the electrodes of the ionisation gauge bombarded.

The greases and oils thus obtained are now well known under the trade name "Apiezon" products, sold by Technical Products, Ltd., London, and others. The vapour pressures at room temperature are 10^{-5} mm. Hg and 10^{-7} mm. Hg for Apiezon oils A and B respectively.

While the Apiezon oils and similarly the "Molecular Lubricant" of Litton Engineering Laboratories, California,[85] are produced by distillation of natural substances, synthetic organic working fluids were introduced by Hickman and his collaborators at the Kodak Laboratories in U.S.A. The purpose was to overcome certain difficulties which had been experienced with natural hydrocarbons, *e.g.*, inferior pumping speed, decomposition and charring with continued use. The first product used was dibutyl phthalate[86] which proved to be sufficiently stable, *i.e.*, it produced the least amount of volatiles on boiling. But this substance had still a comparatively high vapour pressure and further aromatic and aliphatic esters were developed which are applicable to lower ultimate pressures. The table[87] overleaf shows some of the properties of the pump oils now recommended by Distillation Products Inc. (Kodak & General Mills):

Another organic compound used in oil diffusion pumps and recommended by the National Research Corporation, Boston, is known under the name of Narcoil. It is a chlorinated aromatic hydrocarbon.

It should be mentioned that the values for C in the above table are those claimed by the manufacturer. Recent investigations[87a] made by J. Blears showed much higher values.

Properties of Some Pump Oils

Name	Formula	A	B	C	D
Butyl Phthalate	$C_6H_4(COOC_4H_9)_2$	278.1	1.0465	4×10^{-5}	80
Butyl Sebacate	$C_8H_{16}(COOC_4H_9)_2$	314.3	0.993	2×10^{-5}	90
Amoil ...	$C_6H_4(COOC_5H_{11})_2$	306.2	1.0190	7×10^{-6}	100
Amoil S ...	$C_8H_{16}(COOC_5H_{11})_2$	342.3	0.9251	2×10^{-6}	111
Octoil ...	$C_6H_4(COOC_8H_{17})_2$	390.3	0.9796	2×10^{-7}	122
Octoil S ...	$C_8H_{16}(COOC_8H_{17})_2$	426.3	0.9103	5×10^{-8}	143

A=Molecular weight.
B=Specific gravity at 25° C
C=Ultimate vacuum attainable with fractionating pump at 25° C.
D=Boiling point at 10^{-2}mm Hg.

A few words should be added on the use of fractionating pumps. They have been developed for the purpose of avoiding the injurious effects of decomposition products of natural or synthetic oil on sensitive parts of the system to be evacuated. Thus, for instance, while organic fluids have little or no effect on tungsten or thoriated tungsten cathodes, oxide coated cathodes are injuriously affected. There are also other reasons for refining the organic working fluids used in diffusion pumps. Even the purest liquids acquire impurities either spontaneously or through interaction with gases and vapours passing through the pump. Due to these impurities and to highly volatile compounds of the working fluids the accepted condition that the pressure obtainable by a diffusion pump corresponds to the vapour pressure of the working fluids is seldom fulfilled in actual work. Especially if an oil diffusion pump is used for molecular distillation permanent gases are slightly, and vapours extremely, soluble in the working fluid; the pump becomes contaminated and the pump speed diminishes.[88] The desirability of removing the decomposition products and the highly volatile compounds was simultaneously recognised in England and U.S.A. and many designs were proposed for overcoming the difficulties. It should be mentioned that the purification of mercury by distillation in connection with a mercury jet pump was proposed by Stintzing.[89] Gaede described an oil diffusion pump made by Leybold, Cologne, according to his design in which by a special adjustment of a multiple water cooling system a fractional distillation of the working fluid was accomplished inside the pump.[90,91] While McCowen and Fawcett of I.C.I., purified the working fluid in an external distillation column,[92] self-purifying or fractionating pumps were devised in which "the various constituents of the unpurified organic working liquid are separated and take up their appropriate working positions in the system."[88]

In Lockenvitz's[93], Mahler and Marcuwitz's[94] and Sykes and Bancroft's[95] designs the evaporating zones are formed by vertical concentric tubes while Hickman prefers the horizontal design for his glass and his all-metal types. For more detailed information on the development of the fractionating pumps the reader may be referred to Hickman's article of 1940.[96]

Repeatedly it has been proposed to use other inorganic vapours instead of mercury vapours in diffusion pumps, *e.g.*, lead, tin, bismuth, cadmium, zinc or the like.[97] Gallium, either pure or compounded with aluminium, has also been recommended,[98] and so have other fusible alloys, *e.g.*, Woods metal.[99] But the drawback of all these materials solid at room temperature is that great quantities of the medium condense out in the solid form at the limits of the cooling areas and will finally plug the passage ways.[85] The same may be said of a proposal made by Klumb[100] to use solid paraffin either alone or in addition to fluid pump oils in order to reduce the gas absorption of pump oils exposed to air. Also a high heat input is required if solid paraffin is used. Other proposals of the same author[101] try to combine the advantakes of mercury and oil used as pumping fluids, without their drawbacks, by either using a non-condensible vapour of phthalates, paraffin or metals between a mercury vapour pump and the recipient, preventing mercury vapour from entering the latter, or by combining two pumps, one for the low vacuum stage worked by mercury and one for the high vacuum stage worked by oil. This latter arrangement is used in a pumping outfit manufactured by Gaiffe-Gallot et Pilon, Paris.[102]

Diffusion pumps designed for use with mercury are in general unsuitable for use with oil for the following reasons: the throat of the pump may be too small and be bridged by an oil film; the cross section of the jet and of the vapour uptake may be too small, so that sufficient oil can only be conveyed by overheating it; excessive condensation may occur if jet and uptake run too cool. But small glass pumps may be worked by mercury or oil, and a 2-in. all-metal pump designed by the National Research Corporation is also suitable for use with either working fluid.

While the inorganic vapours thus far named—other than mercury—will probably not play an important part in future development, quite recently high boiling silicones manufactured by Dow-Corning Glass Works have been investigated which have a very low vapour pressure and are nearly completely resistant to oxidation when exposed to air while hot.

Some metals when hot act as catalysts to the cracking of oil, while some metals, particularly copper, are corroded by hot oils. The use of silicones may permit the operation of the boilers at higher temperature and pressures. The pump can be opened while it is still hot as the silicone is stable at the temperatures used.

The silicone oils are semi-inorganic polymers in which carbon atoms of organic radicals are linked to the silicon atoms of the so-called siloxane chain. The Si-O-Si linkage is strong, heat resistant and unaffected by water or sunlight. Also the Si-C bond is strong. The fluids do not decompose on exposure to moist or dry air and are chemically inert to aluminium, brass, copper and steel. Their vapour pressure is as low as, or even lower than, that of the best organic pump oils. Their recovery time after exposure to air is remarkably short. Vacua of less than 5×10^{-8} m mHg. are claimed to have been attained. But it must, of course, be remembered that for pressures below 10^{-6} mm. Hg it is very difficult to state (a) what the pressure actually is, and (b) where it is, because no equilibrium is obtainable in a system. Also the pressures of nearly all substances become disturbing.

The properties mentioned will certainly lead to a very extensive use of silicone pump oils in future, the more so since they may be used in non-fractionating pumps.[103] These pump oils, as well as the silicone greases for high vacuum work, are supplied in this country by Edwards & Co.

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(To be continued)

Diamonds as Radiation Detectors

From the National Bureau of Standards Report, November 1947

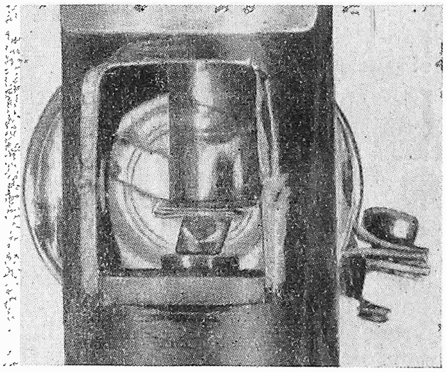
RADIOACTIVITY studies conducted by L. F. Curtiss of the National Bureau of Standards radioactivity laboratory have shown that diamonds are highly sensitive to gamma rays and may be used to detect this radiation in the same way as a Geiger-Müller counter. It has been found that a diamond placed in a strong electric field initiates sharp electrical pulses when gamma radiation is absorbed, and, as with a Geiger counter, a count of pulses gives an indication of the intensity of the radiation. The diamond counter has not yet been tested for beta radiation, but it is expected that a similar effect may be observed in this case.

To use a diamond as a counter, it is clamped between two small brass electrodes maintained at a difference of potential of about 1,000 volts. When a source of gamma radiation is brought within range of the diamond, there occur across the electrodes pulses of current, which after amplification may be detected and counted on any suitable indicating device.

The pulse-producing property of the diamond is thought to be a result of its highly symmetric crystalline structure, characterised by a very regular arrangement of carbon atoms with relatively large intervening spaces. According to this theory, when a photoelectron is emitted by a diamond atom as the result of the absorption of gamma radiation, the freed electron is accelerated through the interatomic space toward the positive electrode. Within a very short distance it acquires such high velocity that other atoms along its path are ionised by collision with the release of additional electrons, which in turn are accelerated in the same direction. This multiplication of charges repeats itself in rapid succession, producing a sudden avalanche of electrons equivalent to a small pulse of current. The larger the diamond, the more electrons would be involved in the sudden pulse that is counted. This means that the gamma-ray sensitivity of a diamond counter should be proportional to the size of the crystal. However, adequate sensitivity is obtained with a comparatively small diamond. Apparently the diamond quickly recovers from its ionised state, as the pulses registered are extremely sharp. The diamond counter is thus a very "fast" counter, capable of indicating a much greater number of pulses per minute than is possible with the ordinary Geiger-Müller counter.

Industrial diamonds used as counters must be colourless and absolutely free of flaws; about one diamond in forty meets these specifications.

Diamonds tested in the Bureau's laboratories have been found to have a sensitivity per unit volume equal to or greater than that of any counter constructed by man. One



A diamond mounted in the counter chamber

of these diamonds, measuring about $\frac{1}{8}$ in. on each face, has approximately the same sensitivity for gamma radiation as a laboratory-constructed Geiger-Müller counter of the usual type. Many diamonds are larger and would thus be much larger and would thus be much more sensitive. There is no appreciable cost difference between the diamond and an ordinary counter. However, one of the important advantages of the diamond counter, in addition to sensitivity and long life, is its small size, permitting use inside the human body or in small openings in industrial equipment.

In view of the relative abundance and moderate cost of industrial diamonds, as well as the simplicity and apparent indestructibility of the diamond counter, it is probable that Geiger-Müller counters may be replaced by diamond counters for many applications.

Magnetic Amplifiers

By S. E. TWEEDY, B.Sc.*

Part 2.

Design and Performance

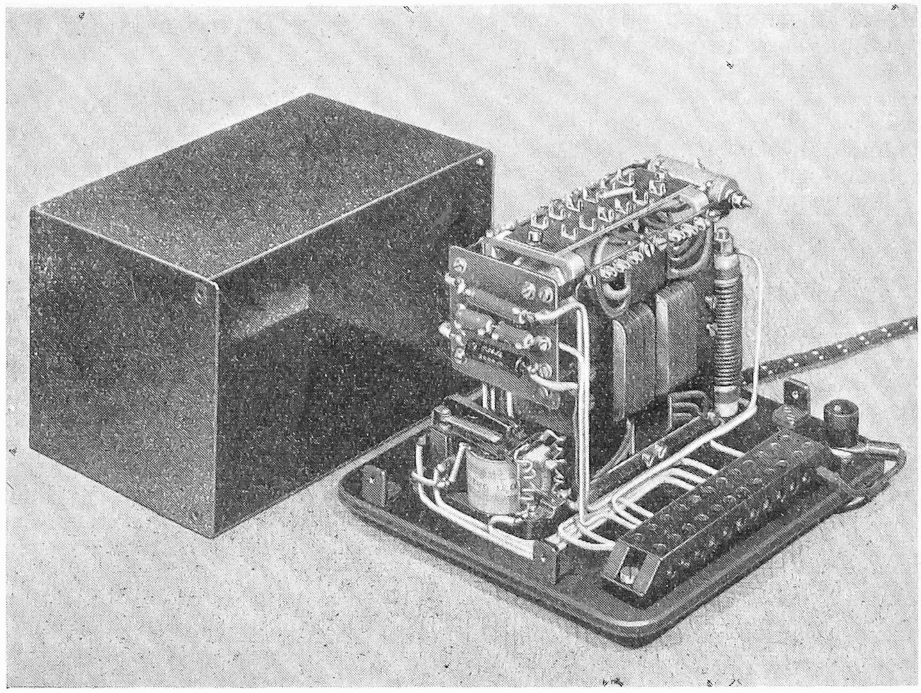


Fig. 17. A typical magnetic amplifier

Self-excited Transductors

IN a preceding article the characteristics and design procedure for transductors cored with mu-metal was discussed, and it was seen that such devices may give an amplification between the power dissipated in the D.C. windings and the power controlled in the load, values up to about 400 or so being obtainable. It was pointed out though that high gains were only obtainable when the maximum output power demanded was considerably lower than the possible value obtainable from the given frame size.

We shall now discuss magnetic amplifiers proper, in which high gains are realisable without such a limitation. Such magnetic amplifiers are distinguished from the transductor by their employment, in one form or another, of self-excitation.

In one type of self-excited transductor a second D.C. winding carries the A.C. output current after rectification. The winding is therefore sometimes referred to as a feed-back winding. For practical and design considerations, this self-excitation current may be considered as an additional D.C. current, whose effect is identical to that of the separate D.C. currents controlling the simple transductor, although this is not strictly true due to the pulsating nature of the former. We shall, however, use this concept in the following analysis.

The curve CAB of Fig. 10 represents the relation between the average A.C. output current and the D.C. current of a particular transductor at a given A.C. voltage. Such curves are easily derived from measured characteristics such as those of Fig. 8.* For other A.C. voltages the corresponding curves will be close to the one drawn, over the central straight portion which is the portion corresponding to the dotted parallelogram in Fig. 8. This curve, in the case of a self-excited transductor, represents the relation between the average A.C. current and the *total* D.C. current which latter is comprised of the self-excitation current, the control current and, perhaps, a bias current.

Now the self-excitation current (ignoring rectifier imperfections) is at all times proportional to the A.C. *output* current. We may therefore draw a line such as OD to represent this relationship, the slope of the line depending on the degree of self-excitation (measured in ampere-turn ratio) employed. Supposing that no additional D.C. current is flowing, the working point must be on OD and must also be on CAB. The amplifier will consequently work at E, the point of intersection of these two lines, and an A.C. current OH will flow.

To cause the working point to rise to G, say, a signal of amount FG only is required, since JF is provided by the self-excitation. In this way, characteristics such as are drawn in Fig. 11 are obtained, which show the relation between output current and control current for an amplifier having a fairly high self-excitation. The separate curves refer to different A.C. supply voltages.

An interesting property of the arrangement is evinced when the self-excitation is over-dimensioned. In Fig. 12 the characteristic CAB of Fig. 10 is re-drawn, together with a line OD representing such a self-excitation. In the absence of a signal, the working point is evidently D. If a signal opposing the self-excitation is applied, lines parallel to OD and displaced horizontally by the amount of the signal may be drawn. At a signal of value OJ, for instance, the working point will be at K. For a signal of value OF, however, which is just greater than that for a line tangential to CAB at E, the A.C. current will suddenly fall, the working point becoming N. Now if the signal is re-established at OJ, the working point will be L instead of K. When the signal falls to OH, which is just less than that for a line tangential to CAB at G,

* Electro Methods, Ltd

* *Part 1, p. 42, February issue.*

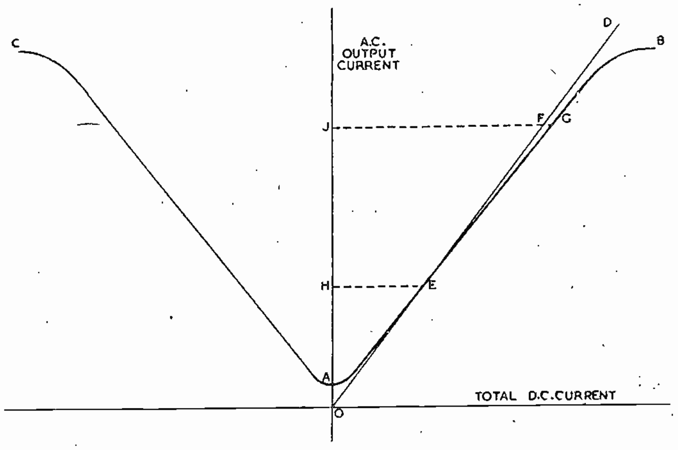


Fig. 10. Action of self-excitation

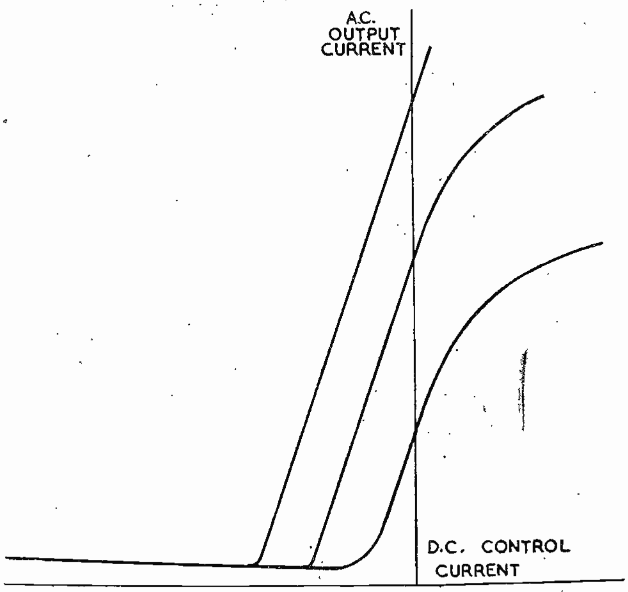


Fig. 11. Typical characteristics with self-excitation

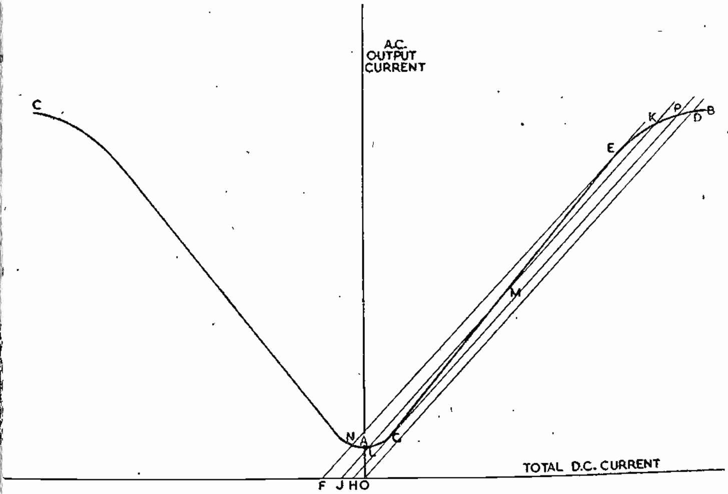


Fig. 12. Action of over-dimensioned self-excitation

the A.C. current will suddenly rise, the working point being P. It should be noted that working points such as M are unstable. This results in a characteristic of the form shown in Fig. 13, which is useful in cases where a trigger action is required.

Design of Self-excited Transductors

Design procedure for self-excited transductors follows closely that for the simpler types, and is best based on an E-I characteristic. It is therefore of interest to consider the effect of self-excitation on such a characteristic, particularly within the area of the parallelogram of Fig. 8. Within this area, the lines for various constant control current remain parallel equi-spaced straight lines, but as the self-excitation is increased, so they gradually move further from the vertical. In fact, when the self-excitation is of the order of 100 per cent., they become nearly horizontal. At self-excitations well over 100 per cent. they even move to the opposite side of the horizontal, resulting, as has been seen, in instability when the control current is varied while the A.C. supply voltage is held constant.

In addition to this change in slope, the lines become more spread out, *i.e.*, the perpendicular distance between two lines for the same increment in control current becomes very much greater. In proportioning the various windings, the wattage dissipation of the control winding is generally so low that it may be neglected in considering the thermal rating. The A.C. and self-excitation windings are therefore dimensioned according to the thermal limit at maximum output power, while the control winding and (if necessary) the bias windings take up the remainder of the available space. Knowing the volume of the D.C. winding and the input power, the controlling ampere-turns available are readily calculated and the self-excitation may therefore finally be trimmed to suit.

It will generally be necessary to incorporate a bias winding, carrying a constant D.C. current, derived, for example, from the A.C. supply voltage over a rectifier. Thus, if it is found that the desired range of output is achieved over a control from, say, -0.8 to $+0.2$ ampere-turns, while the input available ranges from 0 to 1.2 ampere-turns, a bias winding supplying about -0.9 ampere-turns will be required. The remarks about the neglecting of the control winding wattage in considering the thermal rating usually apply equally well to the bias winding.

Although theoretically it is possible to deduce the E-I characteristics for a given self-excitation by assuming the principle of "equivalence" between the self-excitation current and other D.C. currents, in the manner described or in other similar ways, it is in practice rather difficult, particularly at self-excitations approaching 100 per cent. This is because of the fact that slight errors in determining the original characteristics become highly magnified in the process. Imperfections of actual rectifiers is another contributory factor. This means that a good design should provide means for final trimming of the amount of self-excitation actually employed. In the same way, a precise calculation of the amount of bias necessary is tedious and generally unreliable and it is a wise precaution to make provision for the final setting of the bias to the optimum value found on final test.

The self-excitation winding has been referred to in the foregoing as a separate winding. Circuits are known, however, in which the self-excitation current is caused to flow in the A.C. windings, and a typical example is shown in Fig. 14. Here the transductor is essentially a parallel transductor. The provision of the rectifying elements means that an A.C. current cannot pass unless a D.C. current of the same value flows in the closed circuit comprising the rectifiers and the transductor windings. There being no reason why this circulating D.C. should be larger than that required for A.C. to pass, it follows that the D.C. ampere-turns caused by this current are equal to the A.C. ampere-turns, *i.e.*, the circuit has 100 per cent. self-excitation (actually rather lower due to losses and rectifier imperfections). The disadvantage that the amount of self-excitation is fixed may be overcome by adding a few extra turns over a further rectifier in the A.C. circuit, in the sense desired.

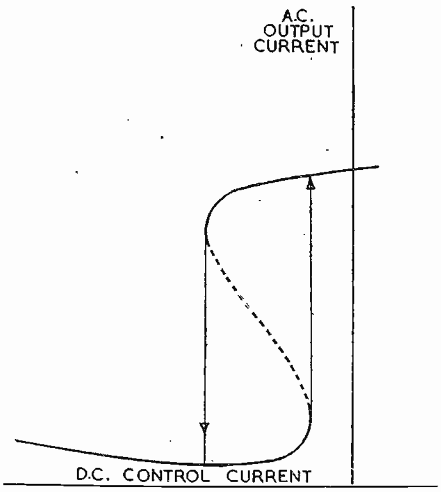


Fig. 13. Typical Characteristic with over-dimensioned self-excitation.

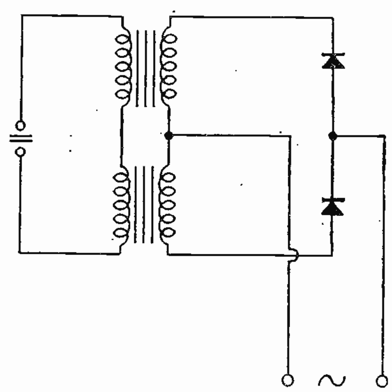


Fig. 14. Arrangement with commoned A.C. and self-excitation windings.

Push-Pull Amplifiers : A.C. Output

It is apparent from Fig. 11 that the use of considerable self-excitation results in a loss of the property that the output current is largely independent of variations in the A.C. supply voltage. In fact, such variations can cause very large changes in the output current. To eliminate this draw-back, magnetic amplifiers are very commonly operated in push-pull, and a typical circuit for a push-pull amplifier having an A.C. output is drawn as Fig. 15.

Two magnetic amplifier units are used in this case, having input windings connected in series in such a way that the input assists the self-excitation current in one unit, whereas the two oppose in the other. A transformer, having a centre-tapped secondary, supplies A.C. and the load is connected in the centre-tap lead, being thereby common to the two amplifier circuits.

It is evident that due to the circuit symmetry, and provided the two units are identical, there will be no current in the load if there is no input, even if the supply voltage and frequency changes. When an input current flows, the current in one amplifier unit rises and that in the other falls, the difference flowing through the load and creating the useful output power. It is necessary to ensure that the amplifiers are working at the maximum sensitivity, and to this end it is sometimes necessary to include in each amplifier unit a bias winding. These windings magnetise the cores in the same sense as the self-excitation windings in each unit, or in the opposite sense in each, and consequently the inherent symmetry is not lost.

If the load is varied in impedance and the power amplification measured for a given input, it is found that for a certain load impedance the amplification becomes a maximum. The value of this optimum load depends on the amount of self-excitation used to a certain extent, and very much on the number of turns used for the A.C. windings of the amplifier units, varying, in fact, directly with the square of the number of turns. The design procedure for such a circuit therefore consists of choosing the amount of self-excitation to give the required amplification and then adjusting the number of turns of the A.C. windings so that the load in question is the optimum load. This is best done by comparison with measured cases. It is also possible to connect the load across the secondary of a trans-

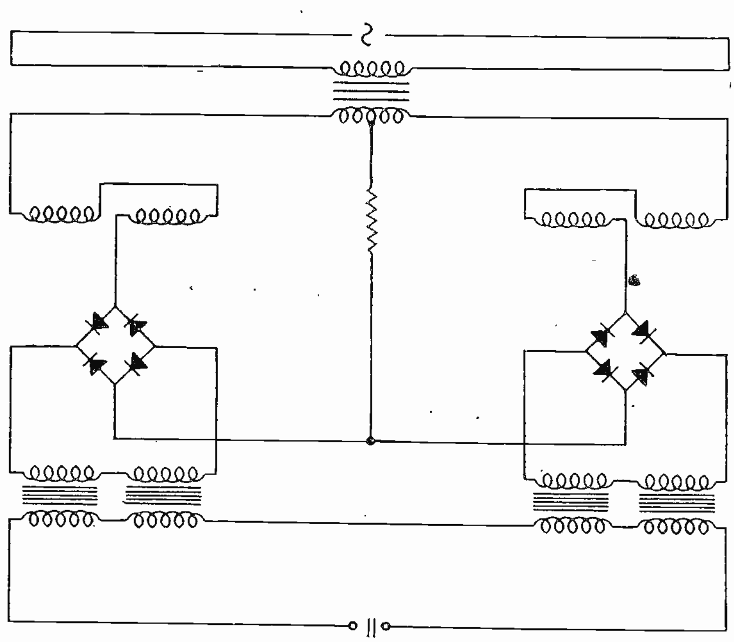


Fig. 15. Push-Pull amplifier with A.C. output.

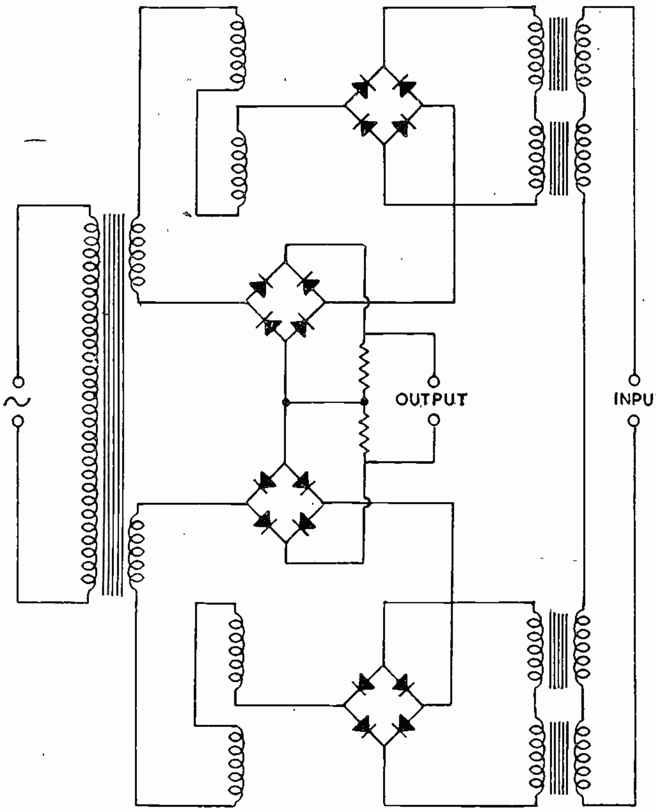


Fig. 16. Push-Pull amplifier with D.C. output.

former whose primary is in the centre tap lead of the supply transformer, the ratio of the transformer being such as to make the load impedance as seen by the primary side equal to the optimum load (compare speaker transformers).

Push-Pull Amplifiers : D.C. Output

Often it is required for the output to be D.C., the polarity of which depends on the polarity of the input. A typical push-pull circuit possessing this feature is shown in Fig. 16. The supply transformer now has two separate secondary windings, each of which feed a circuit comprising an amplifier and a resistance over a series rectifier. These two resistances are commoned at one end, and the output is taken over the two in series opposition. Such circuits are less efficient than the circuit with A.C. output, due to the wasted power dissipated in the resistances.

The remarks made about the circuit having A.C. output apply also to this circuit, except, of course, that an output transformer is not now possible. Each rectifier may, however, be in the secondary circuit of its own load-matching transformer.

Advantages of Magnetic Amplifiers

The main advantages of magnetic amplifiers for the amplification of small D.C. signals may be listed as follows:

(1) They offer an easy and effective means of amplifying D.C. without the need to resort to complicated circuits in order to achieve stability, or to "choppers" in the input circuit.

(2) They are as robust in construction as a transformer, and contain no moving parts, no contacts, no glass, and no filaments. They are therefore practically shock-proof and maintenance costs are negligible.

(3) The input and output circuits are galvanically isolated.

(4) Several input circuits, all galvanically isolated, can be incorporated, the amplifier responding to the algebraic sum of the separate input signals.

(5) An amplifier can readily be designed to match almost any value of load impedance, thus dispensing with the need for output transformers.

(6) The input impedance can be designed and built to suit the conditions of a particular application, over a wide range.

Points (3) and (4) are especially useful when the magnetic amplifier is employed in servo-mechanisms, in which it is often desired to obtain an output dependent on the relative value of several quantities, or on one quantity and various functions of it, such as derivatives, etc.

Construction

In many ways the construction of magnetic amplifiers follows small transformer practice. For single phase units, the core is often of the three-limb type, the centre leg carrying the D.C. winding, while the outer two bear the A.C. windings. The writer prefers the use of two separate two-limb cores, one for each of the two reactors comprising the transductor, in which a better coupling factor can be obtained, without loss in respect of length of magnetic path or of available winding space. The adopted practice in this case is to make a common winding embracing both cores, for those windings which excite each core in the same sense. Thus, the A.C. windings are commonly wound separately on two cores and the self-excitation, bias and input windings are wound over two cores. For push-pull amplifiers this practice can be extended, some windings embracing all four cores. It need hardly be mentioned that, particularly for small units, the air gaps in the core must be kept as small as possible.

In Fig. 17 (p. 84) is shown a typical magnetic amplifier unit* manufactured by Electro Methods, Ltd. This unit will operate on inputs as low as 20 micro-micro-watts and will give stable power amplifications as high as 50,000. It has, in fact, been used at a power gain of just under a million. The unit is capable of an output of about 2-3 watts at a frequency of supply of 50 c.p.s.; at higher supply frequencies the output rises approximately in proportion.

Applications

The following is a list of typical applications where the magnetic amplifier is well adapted to serve:

(1) To amplify a low D.C. signal and feed the output to a switch board type meter; thereby functioning as a sensitive and yet robust galvanometer.

(2) To operate as a pre-amplifier to an electronic amplifier where the incoming signal is D.C.; thereby functioning as a D.C.-A.C. converter, but with the advantage of providing itself a substantial amplification.

(3) To mix and amplify several separate signals; *e.g.*, as a mixing device in a servo system.

(4) To drive and control the reversal of an A.C. or D.C. motor; thereby it can be used as part of an automatic control device. In such cases the signal is frequently derived from a thermo-couple or a photo-cell.

(5) To drive a motor at a speed dependent on the value of the input signal; thereby functioning as an integrating device, *e.g.*, in measurement of fuel consumption.

(6) To supply the control field of an amplidyne.

It is finally of interest to consider in somewhat more detail a particular instrument in which magnetic amplifiers have been successfully employed. The instrument chosen is illustrated in Fig. 18, being the Magnetic Photometer Type MAP 1 developed and manufactured by Electro Methods, Ltd. This instrument was originally developed to replace a galvanometer in equipment used for comparing the spectral reflectivity of painted surfaces, so that tests could be done in the factory rather than being confined to the laboratory. The diffuse reflexion is picked up by a photo-cell of the barrier-layer type and the function of the instrument is to amplify this output so that it can be read by meters of sufficient robustness.

The circuit of the instrument comprises two magnetic amplifier units in push-pull, the arrangement being such that a duo-directional D.C. output is obtained. The amplifier units employed are of the type shown in Fig. 17 and previously discussed. The controls of the instrument comprise a mains switch, a switch in the input circuit, a zero-setting control and an input attenuator control giving variable over-all gain. The fitment of a zero-setting control, while not essential, is desirable in applications of this type in order to compensate for the inevitable slight differences in the two amplifier units, and to allow for any small changes in resistors and other components that may occur with the pasage of time. The variable gain control permits setting of the instrument against a standard reference

Fig. 18. Magnetic Photometer

input (in this case, the input when a white matt panel replaces the surface under test). This useful feature eliminates errors due to long-term variations in light source, photo-cell sensitivity, etc.

The input resistance of this particular model is about 10,000 ohms and at maximum gain full deflection is obtained at an input current of 1-1/3 micro-amps, *i.e.*, an input power of 0.018 micro-watts. The output is developed in an instrument mounted on the panel and calibrated 0-100 per cent., having a resistance of 10 ohms and F.S.D. 5 milli-amps. The output power is thus 250 micro-watts and the power amplification about 14,000. This amplification has been kept low in order to achieve good stability and a linear characteristic, the departure from linearity being less than 2 per cent. of F.S.D. A reading of 1 per cent. of F.S.D. is easily detected, *i.e.*, an input power of 2 micro-micro-watts.

For amplification from sources other than a photo-cell, the input resistance may be wound at any value from about ½ ohm upwards. In such cases, the input power remains constant at 0.018 micro-watts for F.S.D.; thus for an instrument having an input resistance of 100 ohms, F.S.D. will be obtained for about 13 micro-amps.

Acknowledgements are due to Messrs. Electro Methods, Ltd., for permission to publish the above information, and to Mr. F. E. Butcher and Dr. R. Willheim who initiated and directed the development.

References

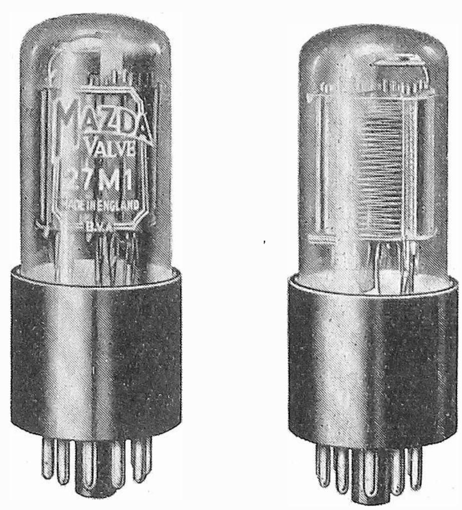
[1] Kramer, W: Ein einfacher Gleichstrommesswandler mit echten Stromwandlereigenschaften *E.T.Z.* 58 (1937) p. 1309-13.
[2] Lamm, Uno: The Transductor-D.C. pre-saturated Reactor, with special reference to Transductor-control of Rectifiers. *Esselte Aktiebolag*, Stockholm, 1943.

New Mazda Electron-Multiplier

RECENTLY announced by The Edison Swan Electric Co., Ltd., is a nine-stage photo-electric electron multiplier Type 27 M.1.

Designed to operate with a maximum potential of 1,250 volts between cathode and anode and a maximum of 250 volts between anode and and dynode No. 9, this device produces a maximum anode current of 2.5 mA. and has a maximum anode dissipation of 0.5 watt with a maximum ambient temperature of 50° C.

With a potential difference of 75 volts per stage the luminous sensitivity is 0.3 amps per lumen, the current amplification (*i.e.*, ratio of anode sensitivity: cathode sensitivity) is 30,000 and the sensitivity at 3,750 A° is 270 micro-amps per micro-watt. If the potential difference per stage is increased to 100 volts these figures become respectively: 2.0 amps. per lumen, 200,000 and 1,800 micro-amps. per micro-watt.

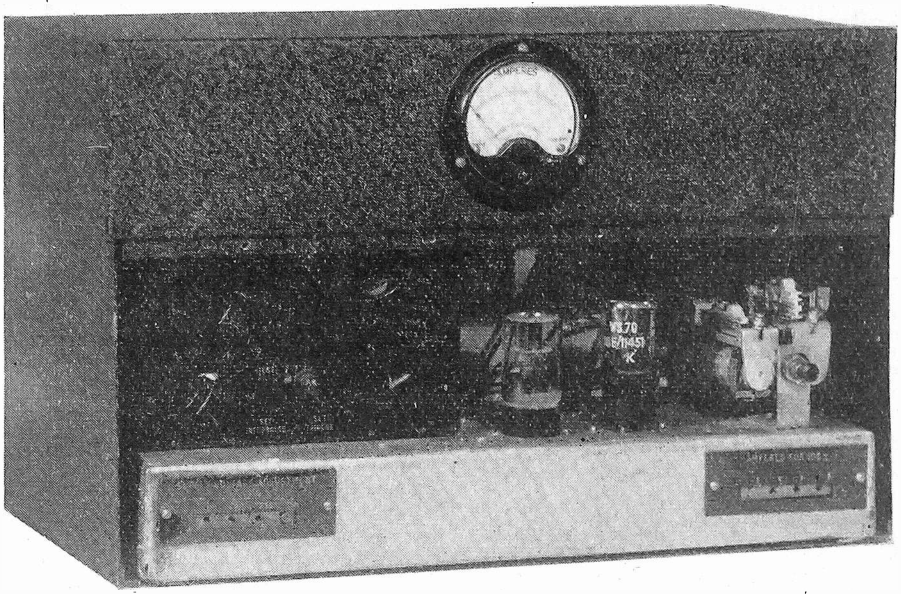


The maximum overall length is 94.0 mm., maximum bulb diameter 28.5 mm., maximum base diameter 33.4 mm. and the distance between seal and light-centre is 49.2 ± 2.4 mm.

No indication is given as to availability.

Basing:

The multiplier is fitted with a Magna 11-pin base, pins Nos. 1 to 9 corresponding with the 9 dynodes. Pin 10 is the anode and pin 11 the cathode. Pin No. 1 is to the left of the key looking at the base from the pin end.



View of Tell-Tale with front panel removed

An Electronic Maximum Demand Tell-Tale

By J. de GRUCHY*
M.Brit.I.R.E.

MOST users of electricity regard "maximum demand" as a problem of recent origin, connected with the fuel crisis of last winter, but in point of fact the subject has exercised the minds of power engineers since the earliest days of D.C. generation.

At that time the cost per unit was set so high that ample profits could be earned without considering the utilisation factor of the generating plant and feeders necessary to cope with the maximum demand.

The move for cheaper electricity, and in particular the creation of the Central Electricity Board, drew attention to the fact that the cost of electricity can conveniently be grouped under two heads, a capital cost representing the necessary generators and equipment including the distribution networks, and a running cost of so much per unit based on fuel prices, labour, etc.

Each consumer should be required to pay his fair share of both costs and in order to achieve this the maximum demand tariff came into being.

The C.E.B. charged the distributors or retailers on a maximum demand basis and the distributors in their turn passed on this charge to all their larger industrial consumers. Maximum demand was defined as the demand integated over a thirty-minute period. It is not within the scope of this article to deal with the question of Kilowatt-hour or Kilovolt-ampere-hour metering. It is sufficient to say that both methods are employed and that the tendency is to use the latter unit where possible so that the consumer is penalised for a low power factor.

In pre-war days the usual charge was of the order of £3 10s. to £4 per Kilowatt so that where it was possible to disconnect some ancillary load, such as publicity lighting or the heating circuit in the managing director's office, considerable saving in the electricity bill could be made.

The Tell-Tale

This situation called for a warning device that would give the consumer early notice when his loading exceeded his estimated maximum. An ammeter fitted with relay contacts was sometimes employed, but it suffered from the disadvantage that the alarm would be sounded by short surges such as are caused by motor starting, etc.

The most satisfactory form of maximum demand tell-tale is an integrating device, operating in the same units as the supply company's meter, but working on a much shorter time period, say five minutes as compared with the thirty minutes they usually employ.

The use of the apologetic term tell-tale with its dictionary definition of "mean informer" or "sneak" indicates the state of mind of its makers. Their trade in instruments was largely with the electricity supply companies, who might easily take a dim view of this effort to reduce their income. That phase is past and gone because the tremendous rise of the domestic load in recent years, with a fantastic tariff based on rateable value instead of maximum demand, has led the supply companies to view with the greatest satisfaction any steps taken by their more orderly consumers to limit their peak demand.

To-day with penalties threatened on all who exceed two-thirds of their 1946 peak demand the need for a maximum demand tell-tale is pressing.

The conventional watt-hour meter and synchronous motor time base is widely employed where the supply company are measuring on a KWh basis. Where, however, the charge is based on KVAh a more complicated integrator is needed.

The electronic instrument to be described* was produced to fill the need for a KVA tell-tale with a minimum of delay in production. It had to employ components "off the shelf" since the urgent demand was for immediate delivery. For the same reason the use of one of the recent timing circuits embodying fed-back time constant was ruled out on account of the delays that a patent search would involve. Instead, a timer circuit which had already been used in a previous instrument was incorporated.

The conventional Kilowatt-hour

* Everett-Edgecumbe, Ltd.

* Prov. Patent

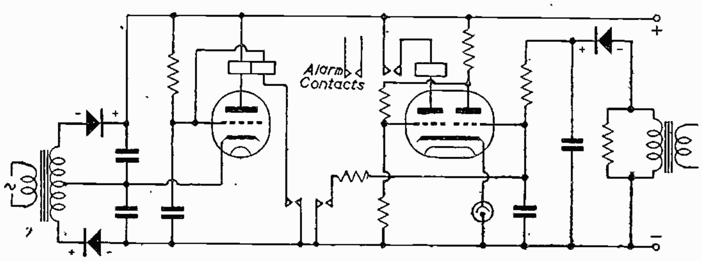


Fig. 1. Basic circuit of maximum demand tell-tale. Both relays are shown not operated. In use, the alarm relay in the anode circuit of the double triode is energised.

maximum demand tell-tale has an induction disk watt-hour movement which is geared to a pointer moving over the scale. An adjustable contact can be set at any point on the scale and the pointer travels up towards it under the influence of the local power demand. At the end of the five minutes timing period the synchronous motor resets the pointer at zero. In effect this is a race between the pointer and the timer. If the timer wins the pointer is reset if the pointer wins and reaches the contact before the end of five minutes the alarm circuit is energised.

The Electronic Tell-Tale

The action of the electronic pattern is analogous inasmuch as a timer circuit defines the five minute period and simultaneously resets the integrating circuit. Once again it becomes a race between the charge on the timing condenser and the charge on the condenser in the integrating network. As before, the action of the timer when it wins is to short circuit both its own and the integrating network condenser, while if the integrating circuit condenser reaches a predetermined voltage before the end of the five-minute period the alarm contacts are completed.

Fig. 1 shows the simplified circuit diagram from which it is seen that a pair of half-wave rectifiers provide a positive and negative rail and that the cathode of the timer takes up an intermediate potential defined by the position of the tap. When the potential between cathode and negative rail is large compared with the grid-cathode potential necessary to operate the relay (say, 1 volt) the timing period is sensibly independent of the applied voltage over wide limits, because the condenser is charging to a proportion of the applied voltage and not to some fixed potential.

Relay 1 has two windings; the first carries the valve current and closes the contacts. The timing circuit condenser discharge current is passed through the second winding of Relay 1 and holds the contacts closed down to a definite condenser voltage so that the restarting voltage is the same in every cycle.

The integrator shown in Fig. 1 is current operated and the voltage term is omitted for clarity. The current transformer feeds a rectifier circuit and the D.C. component is fed to the long time-constant integrating network with the grid of the detector tied to the condenser-resistor junction. The cathode of the detector sits on a voltage regulator tube to give a constant voltage reference towards which the condenser potential rises at a rate determined by the current flowing in the primary winding of the current transformer.

The D.C. coupling from the anode of the integrator detector to the alarm relay valve grid carries that valve beyond cut-off as the condenser potential approaches the reference potential, and so releases the alarm relay, causing the alarm contacts to close. Separate contacts open the anode circuit of the relay valve so that the relay must be reset by hand. The alarm contacts remain closed until the reset button is pressed.

This arrangement of the alarm relay ensures that almost every type of failure that could normally occur will result in the alarm being sounded, thus conforming with the best railway signalling practice. The use of a double triode for the integrator detector and the alarm relay valve ensures that a heater fault in this valve will give the desired result which would not be obtained from the failure of a separate integrator detector valve.

KVA Operation

So much for the simple circuit. For volt-ampere operation the negative rail of the integrator is raised up from the negative rail of the timer by half the voltage of the regulator valve. Only half of the voltage previously required is now obtained from the integrating network. It will be observed that this arrangement does not give true integration of volt-amperes, but an addition of voltage and integrated current. Where the two terms are equal, and they are made equal at the tripping potential, this sum is closely proportional to volt-amperes over the usual range of voltage variation, with the proviso that the volt term is not integrated and so becomes the instantaneous potential in each period.

A true volt-ampere integrator can be provided based on the addition of two D.C. voltages which are made proportional to log E and log I respectively. The complication of the non-linear networks is not justified unless an external indication or

a

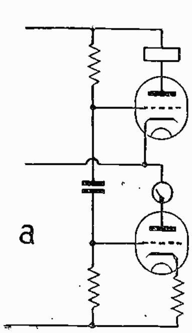


Fig. 2 (a). Timer indicator circuit.

b

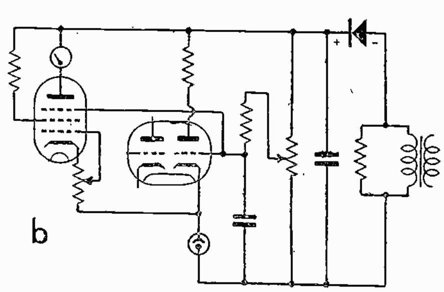


Fig. 2 (b). Integrator indicator and integrator detector.

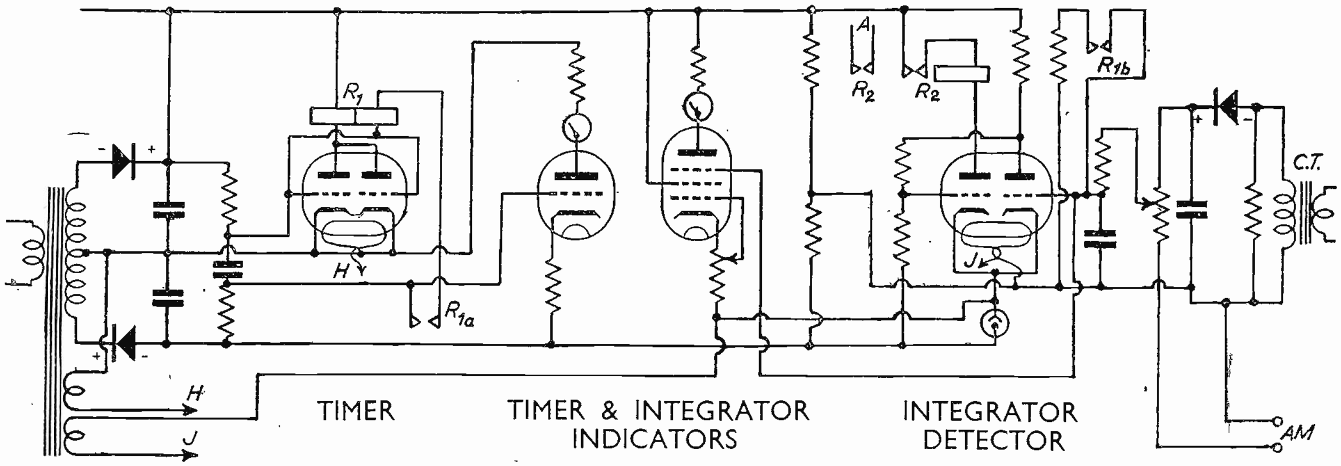


Fig. 3. Complete circuit diagram for integrated current and voltage relay. Both relays are shown de-energised. The alarm relay R_1 is normally energised. A—Alarm contacts.

recording of KVA is required by the consumer.

An advantage of the electronic method lies in the appearance of a D.C. component proportional to secondary current. This D.C. can be taken to any control point in a works to give an indication of instantaneous current. An ammeter can also conveniently be fitted to the instrument panel to facilitate its setting up.

A double check indicator system may be incorporated to give positive indication of the operation of both circuits.

While an electrostatic voltmeter could have been employed for this service to show the rising voltage on the timer and integrator condensers, the low potential of the latter precludes the use of an industrial pattern instrument. Instead, a measurement of charging current is made with a valve-operated micro-ammeter. The timer circuit with its reasonably constant voltage is easy to cater for, but the integrator with its wide range of possible circuit voltage needs some different treatment.

Fig. 2a shows the timer indicator with a small resistor between the timer condenser of Fig. 1 and the negative rail. The indicator has a set-up scale which is marked in minutes of the timing period. Note that maximum current coincides with zero time.

Fig. 2b shows the integrator indicator. The potential on the integrating network condenser carries the suppressor grid of a pentode valve from near anode current cut-off, so that an anode current milli-ammeter indicates the integration of load current. One advantage of this circuit is the relatively large grid base—of the order of 50 volts—which can be obtained with a television pentode valve such as SP61. Another advantage is the ample current which is now made available to operate the indicator. A cathode bias resistor can be varied to compensate for the changes in cathode current.

Thus the indicators may be employed for checking the operation of the relay by placing the pre-set control to the load current shown on the ammeter. The pointers should then rise in step. The timer indicator may be checked against a stopwatch.

The full circuit is shown in Fig. 3 and the preset control is shown as the potentiometer across the rectified output of the current transformer secondary winding. With this potentiometer a fixed voltage is selected to operate the integrating network and the potentiometer scale marking can be in terms of primary current, or where the added potential term is included, in KVA direct, taking into account the current transformer ratio.

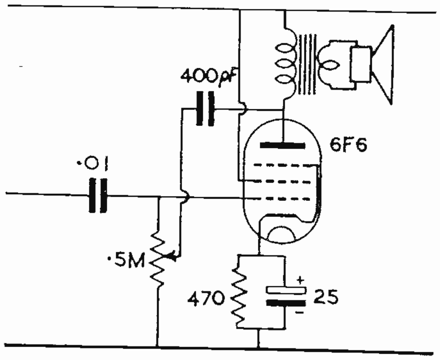
Although the instrument so far described has been designed for single-phase or three-phase balanced load operation, it is obvious that the current term can be obtained from the summation on the D.C. side of three current transformer rectifier combinations to give warning when the total consumption of a three-phase unbalanced load system exceeds the predetermined amount.

A Simple Tone Control Circuit

By G. H. BANTHORPE *

LIKE many other commercial engineers, the writer is forced to spend some of his time in finding ways of saving components with which broadcast receivers are constructed, and has found an extremely simple circuit for a tone control. It has the merit of being not only very satisfactory indeed, but at the same time saves in components.

The circuit is shown below and is seen to be merely a negative feedback arrangement, the amount of feedback depending upon the operating frequency, and the position of the tone control.



The values shown were found, by test, to be most suitable for a typical broadcast receiver. The control has a particularly wide range, but at maximum top cut it gives an attenuation of 28 db. at 20 Kc/s., the attenuation falling by approximately 6 db. per octave as the frequency is decreased.

* Central Equipment Ltd.

The Cathode-Follower

By E. PARKER, M.A. (Oxon), A.M.I.E.E.

Part 3. General Theory

This Part, which deals mainly with methods of constructing exact cathode-follower characteristics, can be read without reference to Parts 1 or 2

10. Numerical Method

10.1. Introduction

THE linear (or "idealised") theory of the preceding sections may not always give the degree of accuracy required (this is most likely to be so if the cathode resistance is small or if the behaviour of the valve at low currents is of particular interest). In such cases the following numerical method giving the *exact* characteristics may be employed. (The word "exact" is used here to mean simply "as exact as the given information about the valve.")

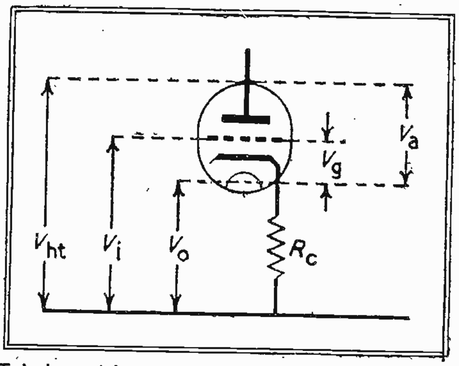
10.2. The Method Described

Suppose first that it is the current characteristic that is required (for an H.T. voltage V_{ht} and a cathode resistance R_c). Let I' be an arbitrarily chosen value of the valve current. Calculate the value of the corresponding cathode voltage from the formula $V_o' = I'R_c$ and the value of the corresponding anode voltage from the formula $V_a' = V_{ht} - V_o'$. Consult the given characteristics (or tables) to find what the grid voltage must be to give a current I' when the anode voltage is V_a'. Let it be V_g'. (V_g' will in general be a negative quantity—*see* paragraph in small type below). Calculate the value that the input voltage must therefore have, from the formula $V_i' = V_o' + V_g'$. This establishes one point (V_i', I') on the required characteristic. By repeating the procedure with different values of I', any number of such points can be found; from these the characteristic may be sketched in.

It is the voltage characteristic and not the current characteristic that is required, the same calculations are made, but V_o', instead of I', is plotted against V_i'.

If V_g' emerges from the above calculations as a positive quantity the value of I' chosen was too large. As a guide to the values of I' that will give admissible (*i.e.*, negative) values of V_g', Equation (7.2) of the idealised theory should be recalled. This sug-

(*continued in col. iii*)



Triode with cathode resistance, showing the parameters discussed in the text

10.4. The Case of $R_c << R_a$.

If R_c is small, then the cathode voltage V_o can never become very great and the voltage V_a across the valve can always be taken as V_{ht}. This means that in the calculation described in paragraph 10.2 above, it is sufficient to know the behaviour of the valve at this anode voltage alone, *i.e.*, to be given the mutual characteristic for $V_a \doteq V_{ht}$ only (*see* Fig. 16a). The cathode-follower current characteristic is then obtained from this mutual characteristic by the simple linear transformation (from the co-ordinates V_g, I into the co-ordinates V_i, I)

$$V_i = IR_c + V_g$$

This transformation represents simply a "tilting-over" of the whole figure until what was the vertical axis in Fig. 16a coincides with the R_c-line Ok in Fig. 16b, horizontal distances (*e.g.*, the bracketed voltages in Figs. 16a and 16b) remaining unaltered. A series of points on the required cathode-follower characteristic can thus be found by marking off along successive lines $I = I'$, from the points at which they cut the R_c-line, voltages equal to the corresponding grid voltages on the mutual characteristic.

gests that values of I between 0 and $V_{ht}/(R_a + R_c)$ should be chosen until the exact behaviour of the characteristic becomes evident. The particular value of I' that gives zero for the corresponding value of V_g' marks the Grid Current Point on the characteristic.

10.3. Example

Let V_{ht} = 300 V and R_c = 500 ohms. Take I' = 5 mA as the first value of I. Then V_o' = 25 V and V_a' = 275 V. Suppose that I' = 5 mA and V_a' = 275 V give the value of V_g' as −2 V. Then $V_i' = V_o' + V_g'$ = 23 V, and the point V_i = 23 V, I = 5 mA has been established on the required characteristic.

11. Algebraic Statement of the Numerical Method

For a given anode voltage V_a there is one, and only one, value of grid voltage V_g that will produce a current I in a given triode. This fact can be written:

$$V_g = \phi(V_a, I) \quad \text{.................} \quad (11.1)$$

where, provided the usual tables or curves relating V_g, V_a and I are available, ϕ is a *known* function even though there may be no recognised mathematical form to represent it. Equation (11.1) is clearly one form of the general equation to the valve triode characteristics (compare the linear Equations (1.1) and (1.2)). Proceeding as in Section 2 and substituting $V_i - IR_c$ for V_g and $V_{ht} - IR_c$ for V_a leads immediately to the equation:

$$V_i = IR_c + \phi(V_{ht} - IR_c, I) \quad \ldots \quad (11.2)$$

which is therefore the general form of the fundamental current equation of the cathode-follower (compare the linear Equation (3.1)). It must also be the formula by which the values of V_i were calculated from the chosen values of I in the previous section; a moment's consideration shows this to be so. First, $V_{ht} - IR_c$ was calculated numerically; then the corresponding value of ϕ was found from the characteristics; this was added to IR_c, and the result was the required value of V_i. Equation

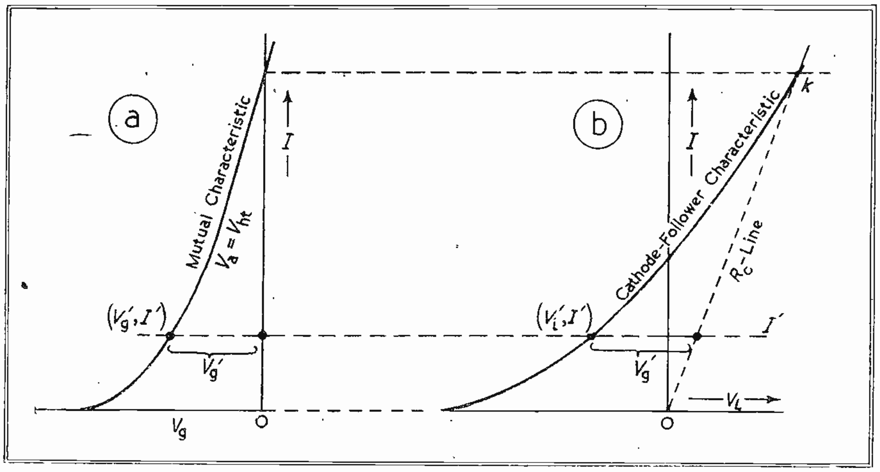


Fig. 16. Construction of a cathode-follower current characteristic from the mutual characteristic when $R_c << R_a$

(11.2) is therefore the algebraic statement of the numerical method of paragraph 10.2.

12. Geometrical Method

12.1. Introduction

If graphs of the anode characteristics of the valve are available, the calculation of V_i for each chosen value of I can be carried out geometrically instead of numerically, as follows.

12.2. The Construction

Suppose as before that it is the current characteristic corresponding to an H.T. voltage V_{ht} and a cathode resistance R_c that is required. On the given anode characteristics graph draw a line passing through the point V_{ht} on the voltage axis and having a backward slope $1/R_c$ (PQ in Fig. 17). On a new graph (*see* Fig. 18) whose axes are marked V_i and I and on which the required cathode-follower characteristic will appear, draw a line Ok through the origin with forward slope $1/R_c$. (It is usually convenient to give the V_i, I graph a more open horizontal scale than the original V_a, I graph had. This has been done in Fig. 18, and also in Fig. 19b, later). Next, draw on each graph the line $I = I'$ where I' is the arbitrarily chosen value of valve current, and let the respective intersections of these lines with the inclined lines be L and M. Let the ordinate through L in Fig. 17 be LN and the intersection of the line $I = I'$ in Fig. 18 with the current axis be T. Let the particular anode characteristic (shown dotted in Fig. 17) on which L lies, be the characteristic $V_g = V_g'$. (The numerical value of V_g' in a particular case can be found by interpolation. It is, for example, about $-4\frac{1}{2}$ volts in Fig. 17). Finally, in Fig. 18, measure off a distance MS equal to V_g' along the line $I = I'$. (Since V_g' will generally be negative, S has been shown to the left of M in Fig. 18). *Then S is a point on the required cathode-follower current characteristic* and by repeating the construction with different values of I' any number of such points can be obtained (*see* S_1 S_2, S_3, etc., in Fig. 19).

12.3 Proof

The validity of the above construction is easily demonstrated. For TS = TM − SM = $I'R_c + V_g'$ (the "+" sign is correct because V_g' is itself negative), = $I'R_c + \phi$ (ON,NL) (using Equation (11.1) and referring to Fig. 17), = $I'R_c + \phi(V_{ht} - I'R_c, I')$ (by the construction of Fig. 17), = V_i' (by Equation (11.2)).

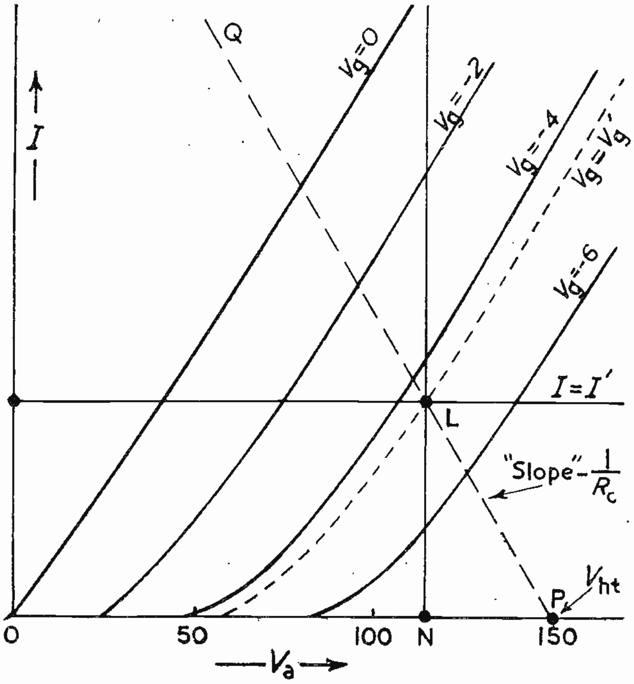


Fig. 17. Conventional anode characteristics

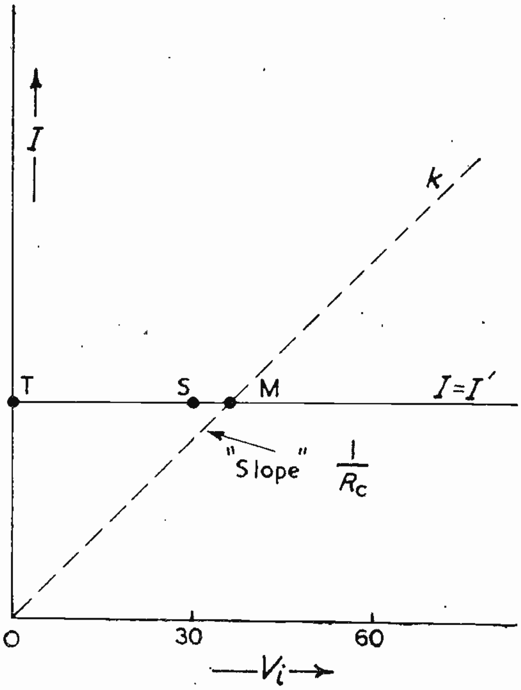


Fig. 18. Constructing the first point

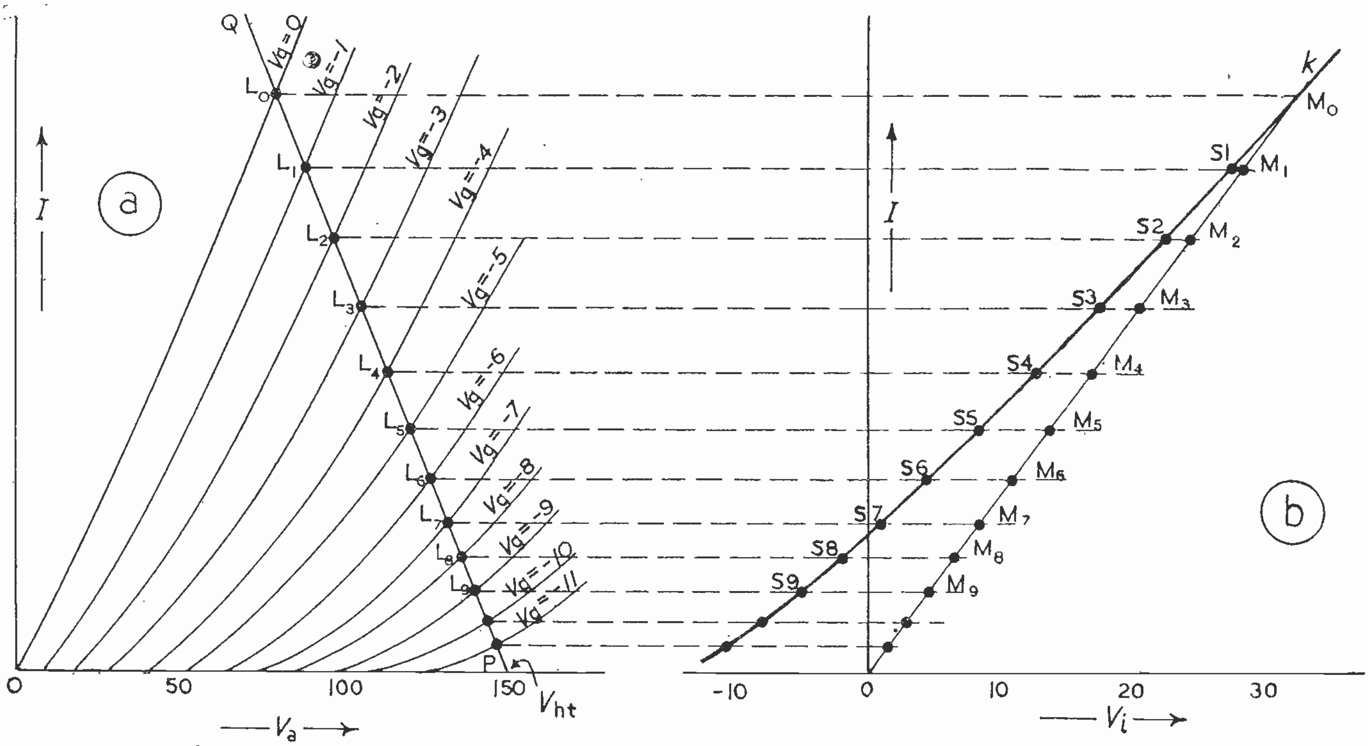


Fig. 19. The procedure for constructing the characteristics

12.4. Practical Procedure

Clearly the simplest way of obtaining a large number of points quickly is to choose lines $I = I'$ which cut PQ exactly at its points of intersection with the given anode characteristics (this avoids the need for interpolation). In other words, draw horizontal lines through some or all of the intersections L_o, L_1, L_2, etc. (Fig. 19a) of PQ with the characteristics. Then, if these same lines are transferred to the graph of Fig. 19b cutting Ok in M_o, M_1, M_2, etc., and if distances 1 V from M_1, 2 V from M_2, etc., are marked back along these lines, a series of points, M_o, S_1, S_2, S_3, etc., on the required characteristic is at once obtained. From this series of points, the characteristics can be sketched in as shown in Fig. 19b.

12.5. " Mirror-Image " Characteristics

Since the slopes of PQ and Ok are numerically equal but of opposite signs, an alternative method is to mark these 1 volt, 2 volt, 3 volt, etc., distances to the *right* of PQ along the $I = I'$ lines of the *original* graph (*see* Fig. 20). If the points so obtained are joined and the completed curve " reflected " about the line $V_a = V_{ht}$ and this line then taken as the current axis of the new "mirror-image " graph (Fig. 21), the result is the same as that given by the previous construction. Fig. 21 shows two characteristics corresponding to different values of R_c (but the same H.T. voltage) derived by this method from the conventional anode characteristics of Fig. 20. The thick curves in Fig. 20 may conveniently be called " *mirror-image* " *cathode-follower characteristics*. It will be seen, further, that the inclined construction lines in Fig. 20 are, in effect, " mirror-image " R_c-lines and also that the Grid Current Points on the " mirror-image " cathode-follower characteristics are their points of intersection with the anode characteristic $V_g = 0$.

13. The Grid Current Boundary Curve

13.1. The Grid Current Boundary Curve Theorem

The last sentence of the previous section leads immediately to the following theorem:

The anode characteristic $V_g = 0$ of any triode, drawn BACKWARDS through the point V_{ht} on the horizontal axis of the cathode-follower current graph, forms the Grid Current Boundary Curve on that graph (*see* Fig. 21.).

13.2 Formal Proof

The general equation to the current characteristic of a cathode-follower whose anode voltage is V_{ht} and cathode resistance R_c is, by Section 11, $V_i = IR_c + \phi(V_{ht} - IR_c, I)$. The Grid Current Point on this characteristic is its point of intersection with the R_c-line $V_i = IR_c$. Eliminating R_c between these two equations gives:

$$\phi(V_{ht} - V_i, I) = 0 \quad \text{.......... (13.1)}$$

which is therefore the locus of the Grid Current Point on the V_i,I graph as R_c varies, i.e., *the Grid Current Boundary Curve*.

On the other hand, the anode characteristic $V_g = 0$ of Fig. 20 has, by Equation (11.1), the equation:

$$\phi(V_a, I) = 0 \quad \text{.................... (13.2)}$$

And by its form Equation (13.1) represents the curve of Equation (13.2) drawn backwards through the point V_{ht} on the V_i axis. Hence the theorem is proved.

13.3 The Grid Current Boundary Line of Section 8

The Grid Current Boundary *Line* that was considered in Section 8 is the special case of the Grid Current Boundary *Curve* when the characteristics are " idealised." It passed through the point V_{ht} on the voltage axis and had a backward slope

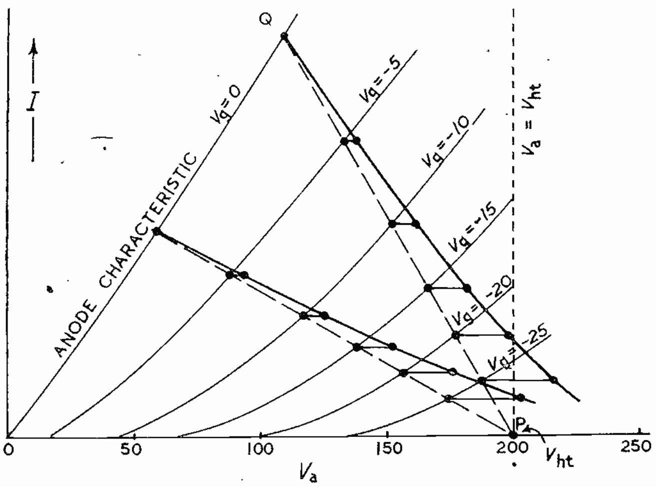


Fig. 20. 'Mirror-Image' cathode-follower characteristics.

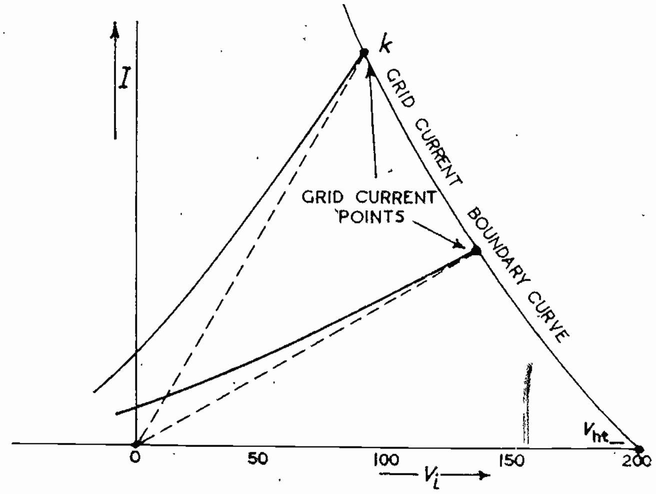


Fig. 21. Fig. 20 reversed.

$1/R_a$, as the general theorem of (13.1) above would lead one to expect.

13.4. Paragraphs 13.1 and 13.2 above assumed the Grid Current Point to be at $V_g = 0$ on the characteristic. If, in fact, grid current starts at some value of grid voltage *other than zero*, it can easily be shown that the characteristic corresponding to *this* grid voltage, when reversed, forms the Grid Current Boundary Curve.

13.5 Alternative Proof of the Grid Current Boundary Curve Theorem

A less formal demonstration of the above theorem can be given as follows. Consider the same valve as before, working with a given H.T. voltage and a given cathode resistance, and let the *input* voltage required to reduce the *grid* voltage precisely to zero be V_i. Let the anode voltage then be V_a. Then clearly

$$V_{ht} - V_a = V_i \quad \text{.................} \quad (13.3)$$

Suppose the valve under these conditions to be passing a current I. Then the point (V_a, I) is a point on the anode characteristic $V_g = 0$ of Fig. 20. Similarly, the point (V_i, I), being a Grid Current Point, is a point on the Grid Current Boundary Curve of Fig. 21. These two points have the same vertical co-ordinates and, by Equation (13.3) above, the first point is the same distance to the left of the line $V_a = V_{ht}$ in Fig. 20 as the second point is to the right of the current axis in Fig. 21. The two points are therefore "mirror-images" of one another with respect to these lines and so therefore are the complete curves—the anode characteristic $V_g = 0$ and the Grid Current Boundary Curve.

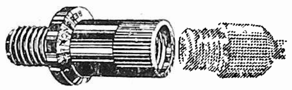
It is perhaps misleading to describe the above as an alternative proof. It is rather an alternative statement of the *same* proof since it is merely the analysis of para. 13.2 put into words. A similar verbal argument can be used to establish the construction of Section 12.

(*To be concluded*)

Interference with Television Reception

A CAMPAIGN to eliminate interference with television reception has been inaugurated by the R.I.C. in accordance with recommendations made by a sub-committee appointed some months ago to investigate the whole matter.

Although television receiver manufacturers, by suitable modifications to the circuit of their current models, have already reduced effects of this interference to a low level, it is emphasised that the most effective means of suppression is at its source. The R.I.C. plan, therefore, is to deal first with interference from car ignition which is the major cause. It is estimated that 85-95 per cent. freedom from such interference can be provided, without detracting from the engine's performance, by fitting 10,000-15,000 ohms resistor in the high tension lead between the ignition coil and the distributor. This method is based on the British Standards Institution's Code of Practice, C.P. 10001, "Abatement of Radio Interference Caused by Motor Vehicles and Internal Combustion Engines." The necessary resistor costs only 1s. 6d. and can be fitted at any garage or radio dealer's establishment or by the motorist himself and is a matter of a few minutes' work.



An ignition suppressor for fitting in the H.T. supply lead from the coil. Nominal resistance 15,000 ohms.

Belling & Lee Ltd.

Some motor car manufacturers, anticipating the campaign, have already designed their engine's ignition systems so that the high tension wires cause a minimum of interference. Others are fitting form of resistors as standard equipment to all cars equipped with radio. The Radio Industry Council is now asking that this should become standard practice throughout the motor car industry, whether cars are to be equipped with radio or not. Garages and service stations are asked to co-operate in "suppressing" cars already on the road as and when the owners visit the garage for service. The National Road Transport Federation, the G.P.O., B.B.C., L.P.T.B., the Railways, Home Office, and the Society of Motor Manufacturers and Traders are all co-operating in the "drive."

A Note on Stabilising Power Supplies

By E. J. HARRIS, Ph.D., D.I.C.*

IT was shown by Miller (reference 1) that the stabilisation of a high tension supply could be improved by feeding a certain fraction of the unstabilised supply into the control system in addition to a fraction of the stabilised supply, as in common practice.

Referring to Fig. 1: a series valve of impedance R_a and amplication factor μ is controlled from an amplifier into which is fed a fraction r_2 of the unsmoothed supply and r_1 of the smoothed supply. In the amplifier these fractions are subject to voltage amplification m_2, m_1, respectively.

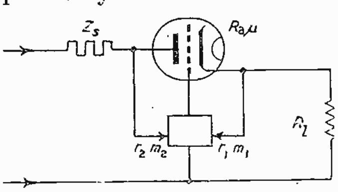


Fig. 1. Basic stabilising circuit.

Suppose a change of supply gives rise to a change ΔV_2 in the unstabilised level and a resultant change of ΔV_1 in the stabilised level; the convention being made that ΔV_1 is of the same sign as ΔV_2. The total control E.M.F. applied to the grid of the series valve is $(r_1 m_1 \Delta V_1 + r_2 m_2 \Delta V_2)$ and the potential drop across the valve changes by $(\Delta V_2 - \Delta V_1)$. For a source impedance Z_s, and load resistance R_L, the current change ΔI brought about is:

$$\frac{(\Delta V_2 - \Delta V_1) - \mu(r_1 m_1 \Delta V_1 + r_2 m_2 \Delta V_2)}{R_a + Z_s + R_L}$$

Now, $\Delta V_1 = R_L \Delta I$

so:

$$\frac{\Delta V_1}{\Delta V_2} = \frac{R_L(1 - \mu m_2 r_2)}{R_a + Z_s + 2R_L + \mu m_1 r_1 R_L}$$

If $m_2 r_2 = 1/\mu$ there is theoretically no change in output level when the supply varies.

It is necessary that the ratio r_2 should not have to be so great that the variation $r_2 \Delta V_2$ appearing at the amplifier is sufficient to swing it outside its operating limits. This implies that there is a minimum acceptable value of μm_2 which is determined by the maximum value of ΔV_2 encountered.

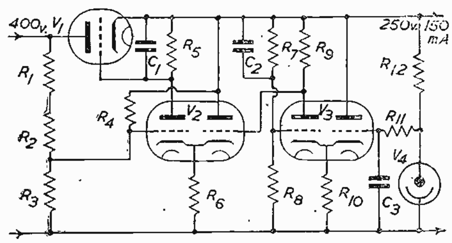


Fig. 2. Miller's Circuit.

Component Values

R_1 2 MΩ	R_7 100 kΩ	C_2 .006 μF
R_2 1 MΩ variable	R_8 75 kΩ	C_2 .05 μF
R_3 50 kΩ	R_9 500 kΩ	C_3 0.5 μF
R_4 25 kΩ	R_{10} 50 kΩ	V_1 3×2A3
R_5 500 kΩ	R_{11} 2 MΩ	V_2, V_3 12 SC7
R_6 100 kΩ	R_{12} 50 kΩ	V_4 VR 105

The circuit used by Miller (Fig. 2) employed two stages of twin triodes (12SC7). Additional stability was obtained by (a) feeding the heaters from the stabilised supply, and (b) applying R-C smoothing to the reference potential obtained from a gas discharge tube. The latter removes the instability due to short-term fluctuations of the operating potential.

It has been found that a multi-grid mixer valve (12SA7) will combine the required mixing action with a high gain (Fig. 3). The reference potential obtained from the gas discharge tube in the cathode circuit cannot be smoothed, but it is found that the VR type of gas discharge tube provides a very stable operating potential. It is again necessary to feed the heater of the amplifier from a stable supply.

The potentiometer $(R_2 R_3)$ across the unsmoothed supply is so adjusted that the mean potential of the junction of $R_2 R_3$ is equal to the cathode potential of the amplifier. The variable potentiometer RV_1 is used to obtain the correct fraction (r_2) of unstabilised supply to apply to the mixer: adjustment may conveniently be made by setting to minimum hum as observed on the stabilised line. The potentiometer RV_2 regulates the output level. The connection of the load resistance of the amplifier to either smoothed or unsmoothed supply introduces negative feedback and reduces the amplifier gain. The effect is small in the former case (*ca* 1 per cent.), and in the latter case it may be cancelled by adjustment of the fraction r_2.

The relevant equations are:

(1) For the anode load returned to smoothed line:

$$\frac{\Delta V_1}{\Delta V_2} = \frac{R_2(R_1 + 2R_L) + R_L(\mu\mu_1 r_1 R_1 - \mu R_{a1})}{(R_1 + R_{a1})(R_a + Z_s + R_{a1} - \mu\mu_2 r_2 R_1)}$$

so for maximum stability:

$$\left(\frac{R_1 + R_{a1}}{R_1}\right) = \mu\mu_2 r_2$$

where:

μ_1 = amp. factor of control grid.
μ_2 = amp. factor of mixer grid.
R_1 = anode load of mixer.
R_{a1} = impedance of mixer.

And (2) for anode load returned to unsmoothed line:

$$\frac{\Delta V_1}{\Delta V_2} = \frac{R_L(R_1 + 2R_{a1} - \mu\mu_2 r_2 R_1)}{(R_1 + R_{a1})(R_a + Z_s + 2R_L) + \mu R_L r_1 \mu_1 R_1}$$

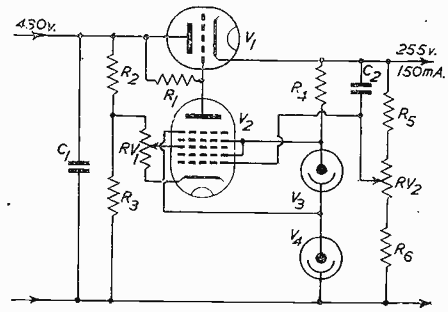


Fig. 3. Use of multi-grid valve

Component Values

R_1 200 KΩ	RV1 20 KΩ	V_3 VR 90
R_2 100 KΩ	RV2 20 KΩ	V_4 VR 105
R_3 33 KΩ		
R_4 10 KΩ	C_1 10 μF	
R_5 150 KΩ	C_2 0.1 μF	
R_6 100 KΩ	V_1 3x PX 25	
	V_2 12 SC7	

for maximum stability:

$$\left(\frac{R_1 + 2R_{a1}}{R_1}\right) = \mu\mu_2 r_2$$

The reason that in practice the anode load is connected to the unsmoothed line rather than to the smoothed line is that the anode current (i_a) of the amplifier valve is limited in the latter case to a very low value. The product $R_1 i_a$ is equal to the operating bias for series valve (say 10 volts). As R_1 is made high (10^5-10^6 ohms) to obtain high gain, the current would be limited to 10-100 μamp. and a low conductance would result.

Some measured performance figures for this circuit are: (a) hum level less than 1 mV

* Biochemistry Dept., University College.

for an output current of 150 mA at 255 volts, with 190 volt drop in the series valves (3 PX 25's in parallel):

(b) Variation with mains level:

Mains level, V	220	236	246
Output level	+1.20	+0.90	+1.15
(Nominal 255 V)			

Over the input range 236 ± 5 V the variation was less than 0.1 volt. The figures for (b) were obtained with choke-condenser smoothing before the series valve. A slight improvement was gained by shunting across the smoothing condenser a series of gas discharge tubes having an operating potential equal to the value of the unstabilised level when the mains voltage was at its lowest. The resistance of the smoothing choke (200 ohms) and of the rectifier was sufficient to limit the current drawn by the gas discharge tubes at higher mains voltages. The measured outputs under these conditions were as given in the table below:

Mains level, V	Output level, V* (Nominal 255
216	+1.12
220	+1.14
224	+1.17
230	+1.18
236	+1.20
241	+1.21

It will be noted that in the circuit of Fig. 3 a 0.1 μF condenser has been shunted across one arm of the potentiometer providing the fraction of the smoothed supply. This increases the value of r_1 for audio-frequencies, but as the general equation indicates, the optimum value of $\mu m_2 r_2$ is not a function of r_1, so no other change in the circuit is necessary.

The output impedance of the system is of importance when a variable load is to be used. For the general case, Fig. 1:

$$Z_o = \frac{Z_s - \mu m_2 r_2 R_a}{\mu(m_1 r_1 + m_2 r_2)}$$

and when the condition $\mu m_2 r_2 = 1$ is satisfied this becomes $Z_o = \dfrac{Z_s - R_a}{1 + \mu m_1 r_1}$

For minimum output resistance for D.C. changes we require in addition $R_a = R_s$ ($Z_s = R_s + jX_s$). If R_a exceeds R_s the output resistance is negative, so the E.M.F. increases as more current is drawn.

At low audio-frequencies the high reactance of the smoothing choke is not effectively shunted by the smoothing condenser so the impedance (Z_s) of the source passes through a maximum value as the frequency is raised from zero upwards. A chain of gas discharge tubes shunting the smoothing condenser reduces the magnitude of this peak value of the output impedance and so improves output characteristic as well as stability.

(Continued in next column)

Another method of applying double control to the amplifier valve has been used by Graham *et al.*[2] The screen of the amplifier pentode was fed from a resistance network across smoothed and unsmoothed supplies, with the disadvantage of an impedance of some 20,000 ohms in the screen supply, so the valve amplification is reduced.

References

[1] *Electronics*, 1941, *14*, 11.
[2] *J. Sci. Instr.* 1947, *24*, 119.

Improving Fly-back Time on a Miller Timebase

By V. Attree*

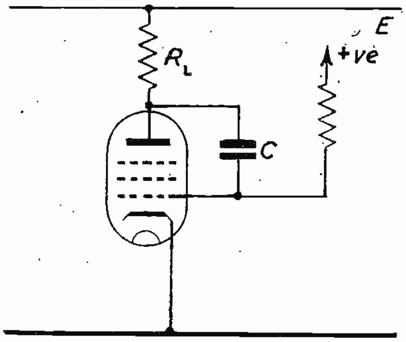


Fig. 1. Flyback time to 99·3% = 5CR_L

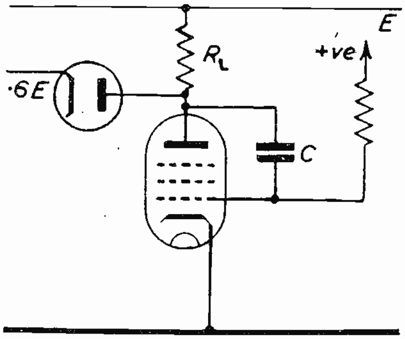


Fig. 2. Flyback time = CR_L

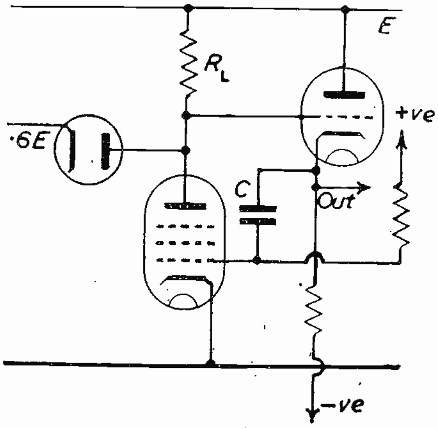


Fig. 3. Flyback time = CR'

With the normal Miller time-base circuit the flyback is exponential and its duration is determined by the product of the charging condenser and the anode load (Fig. 1) *e.g.*, if the anode load R_L is 470 KΩ and the condenser C is 0.01 μF, the flyback will be virtually complete in 5 CR_L or 25 milliseconds.

It is well known that the flyback time may be reduced to about CR_L by "catching" the anode with a diode at a voltage of 0.6 E, where E is the H.T. voltage (Fig. 2). This arrangement does not represent a very great improvement. However, by using a cathode follower (Fig. 3) the flyback time is reduced to CR' where R' is the effective cathode impedance of the cathode follower.

During the major part of the flyback the cathode follower is in grid current, hence R' is larger than $1/g_m$. It is therefore, convenient to estimate the flyback time from the known saturation cathode current of the valve. This current is easily made 40 mA. However, in the case of Fig. 2 with E = 300 V and R_L = 470 KΩ, the average condenser discharge current is only 0.4 mA. Thus, the use of the cathode follower has increased the discharge current by 100 times and improved the flyback by the same ratio. At very high sweep speeds the timing condenser C is small and the flyback is limited by the stray capacity at the anode of the Miller valve instead of the discharge current through C. The improvement in flyback at high speeds is therefore not so great as at medium and low speeds, *i.e.*, the improvement in flyback is most marked at sweep durations longer than about 1 millisecond.

If the condenser charging current is 4 μA the flyback time with the new arrangement is one ten thousandth (0.01 per cent.) of the sweep duration.

The principle has been used in the design of a slow sweep timebase for biological recording having sweep durations between 10 milliseconds and 100 seconds. The flyback time in this timebase in no case exceeds one thousandth part (0.1 per cent.) of the sweep duration. A full description of the circuit is now in course of preparation.

* Biophysics Research Unit, University College

Optimum Frequency Range

By J. MOIR*

IN the January 1947 issue of ELECTRONIC ENGINEERING, the writer reviewed the various attempts that have been made to decide the optimum frequency range for the "most pleasing" reproduction of speech and music. Quite frankly, the available evidence indicates that a non (electro) technical audience prefers a frequency range restricted at the top end to about 5,000-6,000 c/s. rather than the range of some 17,000-20,000 c/s. which we believe is necessary to give a "reproduction" of a full orchestra. It is known that, at least in the case of young people (below 25 years) this frequency range is within the capacity of the human ear. In spite of this it may be said with some confidence that in the majority of tests in which some degree of scientific control was exercised, it has been found that the restricted range of some 5,000-6,000 c/s. was preferred. Although many reasons for this preference have been put forward, that finding most favour is the suggestion that residual distortion, below the level of current instrumental technique or current appreciation, are the real reason for the preference for range restriction. This suggestion was more fully dealt with in the January 1947 issue so that the pros and cons will not be restated, but it is an obvious and necessary step in the investigation to check whether the preference would still be the same if an electro acoustic link comprising microphones, amplifiers, and loudspeakers was not used between orchestra and audience.

Such a test was being undertaken in America at the time the last article was being written and it is the purpose of this note to describe the results obtained.

Although it would be desirable to make the tests on a full symphony orchestra, practical limitations restricted the tests to a six-piece combination of piano, trumpet, violin, clarinet, contrabass, drums and traps, a combination in which the high frequency end of the audio spectrum is well represented.

The orchestra were placed in a section of a room partitioned off

* B.T.H. Co. Ltd., Rugby.

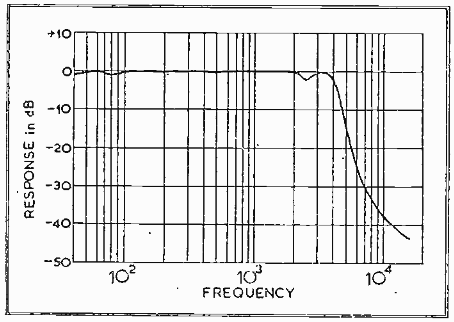


Fig. 1. 'Restricted' frequency range

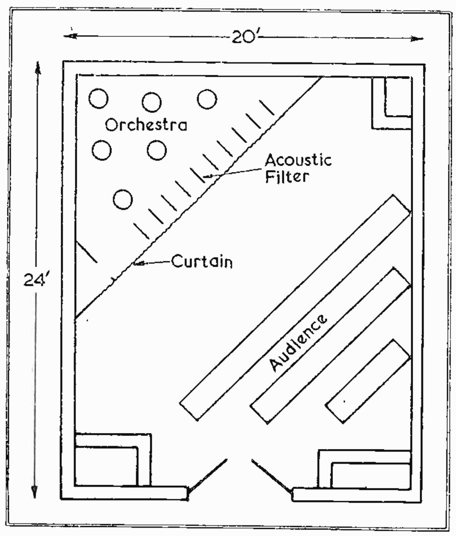


Fig. 2. Test room layout

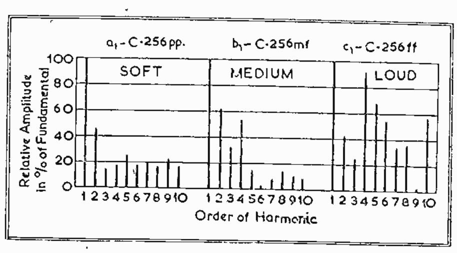


Fig. 4. Typical change in harmonic structure with 'Intensity.'

from the audience, there being an opening approximately 10 ft. by 8 ft. in this partition. This opening could be opened or closed by a series of shutters each about 1 ft. wide and the full opening height, the shutters being pivoted top and bottom so that in the "edge on" position, the opening was substantially unrestricted. The shutter vanes actually constituted the elements of an acoustic filter dimensioned to restrict the frequency range to that indicated by Fig. 1. Dr. Olsen quotes this as being representative of a high quality radio or gramophone equipment, but based on considerable experience the writer would suggest that "exceptionally high quality" is a more accurate description.

Two "frequency characteristics" were available at the listening position "range unrestricted" with the shutters open and "range restricted" to that of Fig. 1 with the shutters closed. These alternative characteristics were presented to the audience as "Position A" and "Position B" at 15 second intervals, while the orchestra played two light musical pieces. The actual shutter position was concealed from the audience by a lightweight curtain and appropriate lighting in order to prevent the result being biased. Separate measurement indicated that the transmission loss introduced by the curtain was only about 2 db. at 10 Kc/s.

Further detail of the actual experimental layout may be noted from Fig. 2 and the photograph, Fig. 3. In a small room of the size indicated even a small orchestra of six pieces can produce more noise than is comfortable and the instrumentalists would therefore tend to exert less effort than is usual in order to bring the sound level down to a pleasing value. It is known that the harmonic spectrum of most instruments is markedly affected by a change in effort, Fig. 4 illustrating the effect in the case of a piano. Any change in harmonic structure would well invalidate the whole experiment, but it was apparently considered that effects of this type were negligible in comparison with the changes in response characteristic.

Each member of the audience was supplied with a card on which to record their preference and any other comments.

The results of the experiment are very interesting. Of 1,000 people who heard the test, 69 per cent. preferred the full frequency range, only 31 per cent. expressing a preference for the restricted range. Divided into age groups the preference remained substantially the

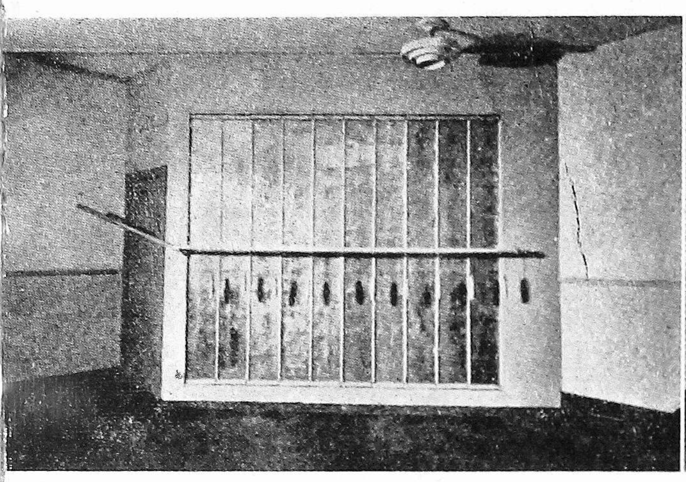


Fig. 3 (a). Shutters 'closed'. Range restricted

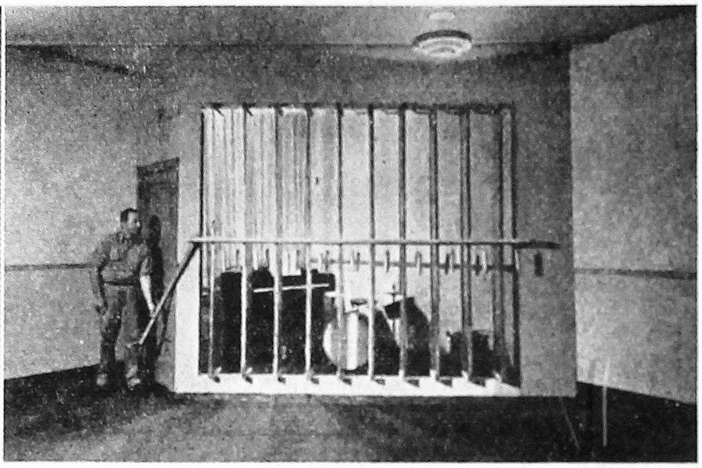


Fig. 3 (b). Shutters 'open'. Range unrestricted

ame except that in the group 14-20 ears the preference for full range vas not quite so well marked, 50 per ent. preferring "full range," while 1 per cent. preferred the restricted ange. This difference is attributed o difference in musical experience, n that this age group would be xpected to have considerable xperience of juke boxes and cheap adio receivers and little experience f real orchestral concerts. To meet he declared objection to light music y a large percentage of the udience some 150 listeners were ested using semi-classical music, but there was no significant change in the results, 66 per cent. preferring "wide range" and 34 per cent. "restricted range."

Comments on the restricted range reproduction are typical of what might be expected of a narrow range reproducer, muffled, muddy, mushy, lacking in intimacy, pushed back, etc., but it is noteworthy that the term "mellow" is not applied.

In a footnote† Mr. Olsen states that "These results are not in conflict with any other published or reported tests" and this appears to be a fair statement of fact. These results are obtained on a binaural listening system differing in many respects from the monaural tests reported in the January issue and these differences may well prove to be the real reason for the apparent preference for a restricted frequency range when a monaural system is tested. The tests are an invaluable contribution to the general effort to narrow the gaps in our understanding of what constitutes good sound quality.

† Olson, Frequency Range Preference for Speech and Music. *J.A.S.A. July* 1947.

CORRESPONDENCE — New Units

DEAR SIR,—I have read with nterest Dr. Grey Walter's letter in our February issue, suggesting a ew unit for the measurement of oltage amplification. Logical coniderations would appear to be all n favour of a unit of this nature.

The comments in your editorial egarding the inadequate consideraion given to suggestions of this ind, cause me to draw your attenion to a letter of mine published n "Nature" during 1945, in which suggested a unit for expressing egree of vacuum, based on similar onsiderations to those used as he basis of Dr. Grey Walter's uggestion.

When considering the adoption of vacuum unit, the proposal was disussed with a number of people ngaged in the field of high vacuum ork, and all appeared to be favourbly impressed by the suggestion. However, subsequent to publication f the letter only two letters were eceived commenting on the proposal. Both were strongly in favour of the idea, one suggesting that the unit be called the "McLeod," in recognition of the work done by this pioneer in the field. This ripple of interest soon faded away, and although the reasons advanced in favour of its adoption were every bit as logical as those advanced by Dr. Grey Walter, it would appear that conservatism is much too strong, and I am afraid that the new Gain units will meet with similar reception.

However, in view of the series of articles which you are at preent publishing on the subject of high vacuum pumps, it is possible that the proposal regarding vacuum units would be of current interest to a number of your readers, and I would be pleased if you could find it possible to allow me to put forward this suggestion again through the medium of your own columns.—Yours faithfully,

F. H. TOWNSEND.

DEAR SIR,—Provided a new unit is going to be useful and accepted by some authority, such as the British Standards Institution, there is no reason whatever why such a unit should not be proposed for a new conception. Trouble only arises when an old name is adopted to cover some new conception. Thus, for *noise-levels* the B.S.I. adopted the German *phon*, while the Americans confused us all by retaining *decibel*, previously defined for power-level differences on a log-scale. I have always been in favour of *hertz* for one-cycle-per-second. It was originated by the Germans and used by myself in an elementary book on acoustics in 1932, but it never caught on here. This is a pity, since one of the greatest pioneers in work which depends so much on high frequencies is not otherwise commemorated in our units: here is an opportunity wasted.—Yours faithfully,

L. E. C. HUGHES.

A Titanium Technique for Metal-Ceramic Seals

By H. W. GREENWOOD

A VALUABLE technique has been developed in the Research Laboratories of G.E.C. Schenectady, N.Y., in which titanium hydride is applied to ceramics in conjunction with a metal such as copper or silver and then brazed to provide a metal-ceramic seal which, it is claimed, constitutes a major advance in the design and construction of U.H.F. and S.H.F. tubes.*

Titanium is no longer looked upon as a rare metal for it is, in fact, much more abundant in the earth's crust than most of our common metals. In nature it occurs mainly as oxide; indeed, the metal until comparatively recently has been a rarity owing to the difficulty of reducing the oxide. In powder form the metal is liable to take fire spontaneously and that property has led, in recent years, to its preparation in the form of hydride, in which state it can be handled and stored quite safely.

Titanium hydride is a stable fine powder of metallic appearance, non-hygroscopic and unchanged in air. When heated there is at first a slow dissociation, hydrogen being given off at temperatures above 350° C. Above 400° C. dissociation becomes more rapid, but is not complete until 1,000° C. is reached. During the whole period of heating the material is virtually in a pure hydrogen atmosphere and no oxidation takes place. It is this condition that is taken advantage of in the new brazing technique to be described.

The higher thermal efficiency of ceramic insulators, supports, etc., and the lower losses than glass is well known, but hitherto the metallisation of ceramics has not been a simple matter. The difficulties are, however, generally appreciated and known and so need not be discussed in detail here. The new technique consists in obtaining a vacuum-tight bond between ceramic and metal which can be used to join up either with other ceramics or with metals by a process which is extremely simple.

It consists in painting the areas of the ceramic with a mixture of titanic hydride and a suitable vehicle at those points or over that area where the seal is required. The paint consists of 300-mesh titanium hydride powder and the vehicle is a fairly thick cellulose nitrate lacquer. The proportions of vehicle to hydride powder should be such as to allow of spreading in a thin dense layer where required, using a brush. As soon as the mixture is applied the metal to be alloyed with the titanium to form the seal is added either as a ring or washer or as a powder. It can be pure copper, copper-silver alloy or pure silver. Copper is best added in the proportion of about 72 parts by weight to every 28 parts of titanium, say, 70 of copper to 30 of titanium hydride paint, as this provides material having approximately the composition of the copper-titanium eutectic.

The treated ceramic is now heated to a temperature of between 900° and 1,000° C., the heating being not too speedy. The hydrogen evolved from the hydride keeps the surface of metal clean and acts as a screen of pure hydrogen during the brazing. At or about 900° silver or silver solder melts and a little above that temperature copper combines with titanium to form the eutectic. The molten metal spreads over the surface of the ceramic and adheres firmly, sealing it hermetically.

The joints can be made in a vacuum and when this is done any absorbed hydrogen is eliminated and dense leak-free metal results. In all cases where ceramic to ceramic or ceramic to metal seals have been tested it has been found that the actual seals have been stronger than the ceramic itself even though it was the steatite or magnesium silicate variety having notably better physical properties than glass. The new technique allows of joining ceramic to ceramic as well as ceramic to metal, while the use of high melting point solders such as silver solder or the copper or silver titanium eutectics as well as the ability of ceramics to withstand high exhaust temperatures permits the production of tubes capable of operation under severe conditions. A further point is the freedom from oxides in the seal which provides a bond resistant to strongly reducing atmospheres and to metallic vapour.

The technique described was developed primarily for use in the vacuum envelope, but it will be obvious that the simplicity of the process as well as the valuable properties of the seals can be used for the permanent attachment of supports and spacers to tube structure such as are necessary in cathode-ray tubes and other units of a similar character, or for the attachment of chromium, molybdenum or other refractory metal wires to ceramic supports. The seals provide rigid and immovable attachments.

It will also be apparent that so simple a technique is applicable in many other fields where ceramic components are used and that there are probably other possible applications in industries other than the electronic.

The following table compares ceramic-metal seals produced by the new technique with the more usual glass-metal seals. The materials are of U.S.A. origin:

Property	Magnesium Silicate (Alsimag No. 243)	Borosilicate Glass (Corning No. 704)
Dielectric constant (10.000 Mc.)	5.5	4.6
Power factor (tangent 10.000 Mc.)	0.0002	0.005
Loss factor (10.000 Mc.)	0.0011	0.023
Volume resistance at 300° C	7×10^{11}	5.17×10^{8}
Volume resistance at 700° C	1×10^{8}	1000
Thermal coefficient of expansion	10.4×10^{-6}	4.9×10^{-6}
Softening temperature ° C	1,440	698
Thermal stability	1000	450
Compressive strength	85,000	70,000 approx.
Flexural strength	20,000	8.000 approx.

* R. I. Bondley *Electronics*, July 1947, pp 97-99.

NOTES FROM THE INDUSTRY

Next Radiolympia in 1949

The R.I.C. is planning to hold the next National Radio Exhibition in the autumn of 1949. This date has been chosen in preference to one in 1948 to enable the industry to concentrate on production for export and to allow more time for the development and production of new sets.

Radio Exports

Exports of all types of radio equipment in November last, amounted to £950,914, of which receivers and radiograms, accounted for £318,700, components and valves £320,917, and £156,535 respectively, transmitters, navigational aids and industrial electronic equipment, £154,762. Biggest importers of British components were the Netherlands, Norway and Turkey which together took over a third of the total. Due to the restriction on imports into India exports of all types of British radio equipment to that country were only 2 per cent. of the total radio exports as compared with 4 per cent. in October and over the whole of the previous year.

New R.I.C. Chairman

Mr. J. W. Ridgeway, O.B.E., of the Edison Swan Electric Co., Ltd., has been elected chairman of the R.I.C. for the current year in succession to Mr. G. Darnley Smith, of Bush Radio, Ltd., Mr. C. O. Stanley, C.B.E., of Pye, Ltd., has been elected vice-chairman.

New Appointments

Philips Electrical, Ltd.

Dr. R. C. G. Williams, M.I.E.E., M.I.Mech.E., has been appointed Chief Engineer of Philips Electrical, Ltd., to advise the Managing Director on all technical matters. He is retaining his recent connexion with America as technical adviser to the North American Philips Co.

Marconi Research

Mr. J. G. Robb, Deputy Engineer-in-Chief of the Company's Research Laboratories, has been appointed Chief of a new Engineering Division in connexion with Associated Companies. He is succeeded as Chief of Research by Mr. R. J. Kemp, who was Mr. Robb's Chief Assistant.

Hivac

Mr. J. R. Hughes, A.M.I.E.E., M.Brit. I.R.E., lately Technical Secretary of the B.R.V.M.A., has now joined Hivac, Ltd. He will be responsible for all technical liaison both with customers and with associated companies.

A Modern Home-Built Televisor

The Second Edition of the booklet describing the construction of this receiver is now available, price 2s. 8d. postage included.

Orders already received are being dispatched as quickly as possible.

Perspex Dyeing

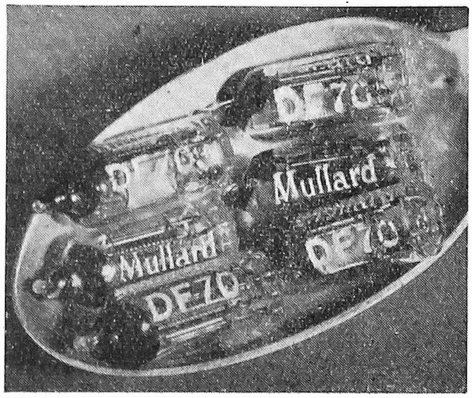
It is not generally known that Perspex, cellulose accetate and similar plastics, including moulded articles can be dyed without damage to the transparency or surface of the materials.

The Dorland Electric Company, Limited, 59 Brompton Road, London, S.W.3, have extensive facilities for the dyeing of such plastics and are able to undertake the dying of plastic parts supplied to them or can fabricate and dye to special requirements. All dyes used by them have been thoroughly tested for light fastness and are permanent. An unlimited variety of colours and shades are available including shades of grey and black and experimental pieces have been dyed with fluorescent substances.

Among the more obvious applications are coloured cathode ray filters, instrument dials, pilot lamp covers, etc. More than this, the process opens up entirely new fields of designs. Used, for instance, in conjunction with the well known "piped lighting" effect of Perspex, indicator lamps can be remotely mounted from the panel resulting in considerable saving in panel space.

Deaf-Aid Valve Contract

Mullard announces that they have recently been awarded a Government contract for 400,000 miniature valves for use in the State sponsored "Medresco" hearing aid. The accompanying photograph gives an indication of the size of the valves involved, six DF.70s being held in the bowl of a spoon.



Six Metre Transmitting Licences

The G.P.O. have advised the R.S.G.B. that its request for the extension of 6 metre facilities had been granted. This means that every U.K. amateur may now obtain a 6 metre licence provided he states in his application that the facility is required for the purpose of conducting technical investigations. The permit will be held valid until April 30, 1948. A charge of 10s. will be made for each permit issued in order to cover the G.P.O's expenses, and this fee should be sent with the application to the Engineer-in-Chief, Radio Branch, W5/5 Brent Buildings, North Circular Road, London, N.W.2.

The Garrard Engineering and Manufacturing Co., Ltd.

Mr. A. C. Marshall, London Sales Representative has now moved to 68/70 Finsbury Pavement, Telephone MET 8927. The Service and Spares Department has moved to Okus Road, Swindon, Telephone Swindon 3405.

The Journal of the Institute of Navigation

This new journal is the official publication of the Institute of Navigation and contains a record of all current navigational work together with reports of the work of the Institute. Besides original contributions of scientific value to air and surface navigation, the journal publishes papers read to meetings of the Institute, and reviews of contemporary books and tables of interest to navigators. It is published quarterly by the Institute of Navigation, c/o. the Royal Geographical Society, 1 Kensington Gore, London, S.W.7., and is available through all booksellers. Price 6s. net, plus 3d. postage, per issue; 25s. net for a year, inclusive of postage.

"Klipin" Circuit Breaker

The "Klipin" circuit breaker has been designed to meet the requirements of a simple, small, and reliable circuit breaker for the protection of small motor appliances, electric tools, lighting circuits, etc., particularly where the initial starting current is greater than the normal running current.

The circuit breaker is operated by a thermal trip and is unaffected by temporary overload.

Sustained overloads open the circuit breaker after a time delay. The tripping mechanism is sensitive and owing to its small mass is not affected by vibration. Calibration — Standard ranges 2.5, 5, 10 and 15 amps. Size—$3\frac{1}{2} \times 1\frac{3}{8} \times 2$ in. Weight—4 ozs.

Obtainable from A. E. W., Ltd., Imperial Works, High Street, Edgware, Middlesex.

BOOK

The Principles and Practice of Waveguides

By L. G. H. Huxley (Cambridge University Press, 1947. 325 pp. Price 21s. net.)

THIS book is a survey of the recent developments in practical waveguide techniques; and the author believes the book does not suffer because of his elementary and physical approach to the subject. The book, in fact, gains from this approach; and readers will agree with his description of the book to the extent that some, if not all, may wonder why the author chose to deviate at all from his strictly physical approach by including the last chapter on Mathematical Treatment.

Although there exist numerous publications on Waveguide Theory, the beginner in the subject is likely to find himself out of his depth from the outset because of its mathematical nature, and the way in which this is greatly divorced from the physical principles. In many ways, waveguide theory is but a guide to the practice. The practice forms a separate subject. Thus the need for a book on physical principles has been felt for some time and, because Dr. Huxley's book sets out to satisfy this need, its recommendation is self-apparent.

Any criticisms of the book must be chiefly concerned with the waveguide devices which the author has included (or omitted) in his techniques, and his description of them. Some of the examples could not be recommended on mechanical grounds; in fact they perpetrate the amateur methods of laboratory workers which were so much experienced during the war. We may ask whether we now require a book on the mechanical engineering of waveguides. This book, in keeping with all its predecessors, fails to recognise that the best waveguide performance is obtained only when the mechanical design is as sound as the electrical. The author describes very thoroughly, and in excellent manner, the application of wavelength principles and impedance concepts to waveguide practice. Now, the wavemeter and the standing-wave detector are pre-eminent in the practical application of these principles, but this book, like all others, is inadequate and trivial in its description of these and other important devices. Some of the waveguide devices which are described represent early examples of the art, and later developments are omitted, but this must naturally result from any book which describes a rapidly advancing art. The article on corrugated waveguides is evidently presented for workers on Linear Accelerators, but the treatment of this complicated subject is sketchy and would have been better omitted. The treatment of impedance transformations, cavity resonators, and slots is excellent, albeit the last is brief. Despite criticism of mechanical principles, which, after all, the author has had to take largely from other workers, the book presents a well laid out description of modern waveguide practice.

This book excels in its treatment of the physical principles. After stating early formulae without proof, in parallel with a description of various waveguides and modes of propagation, the author develops the subject in a logical manner, without disjointedness, using the usual physical and algebraic techniques and analogues which are the accomplishment of the average engineer or physicist.

It is not clear just why the last chapter on Mathematical Treatment has been included in a book of this character. The author says it contains a more formal treatment of the subject. It certainly does; and it also forms an excellent summary of theoretical methods. He may be assured that many readers will diligently study the first six chapters, but few of them will turn the pages of the last. The last chapter is for a different type of reader; one more interested in the theoretical aspects of the subject, who may well prefer his book wholly devoted to a theoretical study. The present book is evidently written for the practical worker, and the beginner.

The time has come for waveguides as a subject to shed its academic appearance and to be regarded as practical, and everyday science. Dr. Huxley's book goes a long way towards this end. The beginner can be recommended to read it in a progressive manner, and be assured that it will lead him along a straight path, cutting out much of the deadwood on the way.

L. W. BROWN

Radio Aids to Navigation

R. A. Smith. 114 pp. (Cambridge University Press. Price 9s.).

THIS interesting little book gives a very full account of the requirements for navigational aids for aircraft and the methods that have been employed to meet them. Radio aids for marine navigation are also discussed but not in such great detail.

In a book of this length it will be evident that there is room only for general descriptions of the systems. No circuit details are given, only the general principles with a discussion of the accuracies obtained or obtainable.

The book opens with a very short but excellent introduction in which the history of radio aids is summarised and the problems of the future postulated.

REVIEWS

Then follows a chapter in which the history is expanded and the different classes of radio aids defined. Thereafter, the chapters are arranged in accordance with the technical characteristics of the systems described.

Chapter 3 gives a full account of the use of beacons by aircraft fitted with radar. This was a natural development from radar and one which it is shown played a very large part in the successful prosecution of the war, both on land and at sea. This is followed by a short account of the use of V.H.F./D.F. and the problems involved. This chapter is all too short since, though conventional direction-finding is rapidly giving place to more modern methods of navigation, it has the great merit of simplicity, a factor, the importance of which is rightly stressed in connexion with other systems.

A short chapter on V.H.F. ranges follows in which the principles are adequately described and chapters 6 and 7 give very full accounts of GEE and LORAN which are easily understood and of great interest, since they are the forerunners of a class of radio aids which is likely to prove most important as large civil aircraft oust their competitors in the field of long-distance transport.

The C.W. systems are described in chapter 8 which is of interest since these systems are not generally well-known. As a contrast, this is followed by two chapters in which the application of radar to navigation is described and discussed. Then follows a chapter on altimeters in which there is only room to describe the different systems very briefly and this leads on naturally to three chapters on blind-landing systems and airfield control. Here the author indicates the lines along which progress is most required if, in future, we are to be spared the tedious delays due to bad weather which are, at present, associated with air travel.

This book is completed by a review of navigational systems and a short, but useful glossary.

To sum up, this is a most useful introduction to, and summary of, the problems of air navigation by radio and the methods of resolving them. Space does not allow a discussion of the design or circuit techniques employed, and if the reader requires this he must obtain the original papers to which reference is made. In this connexion, a bibliography would be of assistance.

As might be expected of the Cambridge University Press, the format of the book is excellent and it is illustrated by clear diagrams and delightful photographs.

J. F. COALES

Working for the Films

Oswell Blakeston. (Focal Press). 200 pp. 10s. 6d.

THE increasing identity of interest between electronics and kinematography lends added value to a book already of outstanding interest, which describes, not how a film is made, but the part played by each technician in the making of it.

Written by nineteen leading technicians, all of whose names are household words to people in the film trade, it covers every aspect of production, from the preparation of the script, to the production and final editing. The film cartoonist, and composer, and the publicity department are not overlooked.

The electronic engineer will of course be primarily interested in the chapter on sound recording. This chapter does not profess to tell anything about the technicalities of the craft, but it does give a useful guide to the jobs of the people employed in that department.

The average person who is anxious to enter the film trade has usually no idea of the wide variety of employment offered, and to him this book can be confidently recommended. Of practical interest to him will be the list of salaries agreed between employers and unions for the various grades.

He will probably not realise a serious omission: that no mention is made of what is probably the oldest training course in the world on the technical aspects of kinematography: the two-year course organised by the British Kinematograph Society at the Polytechnic, Regent Street, London, which since 1931 has turned out many leading technicians and executives.

R. H. CRICKS

Television Explained

by W. E. Miller, M.A. The Trader Publishing Co., Ltd. 52 p. (56 figs.) 3/6 net (postage 2d.)

FOLLOWING the success of a previous book by the same author dealing with radio receiver circuits in a step-by-step survey, it was felt that a treatment of television receiving circuits in the same simple style was overdue, and as a result this book is published.

It is addressed mainly to knowledgeable members of the public who, having some acquaintance of radio circuits, are equally interested in their television counterparts; to radio service engineers as a grounding in the circuitry they will encounter in maintaining television sets; and to students in radio and television in technical colleges.

The book is non-mathematical, and is written in simple language. In addition to television reception circuits, aerials and aerial systems are fully explained, and receiver installation and operation is described and illustrated.

MARCH MEETINGS

Institution of Electrical Engineers

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

Radio Section

Date: March 3. Time: 5.30 p.m.
Lecture: "The Testing of Communication-type Radio Receivers."
By: W. J. Bray, M.Sc.(Eng.), and W. R. H. Lowry, B.Sc.

Date: March 9. Time: 5.30 p.m.
Informal Lecture: "Automatic Telegraphy and Single-side-band Working."
By: A. Cook, B.Sc.

Date: March 24. Time: 5.30 p.m.
Lecture: "Three-Dimensional Cathode-Ray Tube Displays."
By: E. Parker, M.A., and P. R. Wallis, B.Sc.(Eng.).

The Secretary: I.E.E., Savoy Place, W.C.2.

Cambridge Radio Group

Date: March 16. Time: 8.15 p.m.
Held at: The Cavendish Laboratory, Cambridge.
Lecture: "Electronic Calculating Machines."
By: Professor D. R. Hartree, M.A., Ph.D., F.R.S.

Hon. Secretary: J. E. Curran, University Engineering Laboratory, Trumpington Street, Cambridge.

North-East Radio and Measurement Group

Date: March 1. Time: 6.15 p.m.
Held at: Kings College, Newcastle-on-Tyne.
Lecture: "Activities and Equipment of Industrial Electronics Laboratories.
By: G. A. Hickling.

Assistant Secretary: G. A. Kysh, c/o N.E.S., Co., Ltd., Carloil House, Newcastle-on-Tyne.

British Kinematograph Society

Date: March 10. Time: 7.15 p.m.
Held at: Gaumont-British Theatre, Film House, Wardour Street, W.1.
Lecture: "Phase Modulation Principles applied to Sound Recording."
By: J. A. Sargrove, *et al.*
Secretary: R. H. Cricks, 2 Dean Street, London, W.1.

Manchester Section

Date: March 2. Time: 10.30 a.m.
Held at: Manchester Geographical Society, 16 St. Mary's Parsonage, Manchester.
Lecture: "Light Production from the Carbon Arc."
By: H. P. Woods, B.Sc.

Hon. Secretary: A. Wigley, 15 Broadway, Walkden, Lancs.

Institute of Physics

Industrial Radiology Group

Date: March 19. Time: 2 p.m.
Held at: The Institute of Physics, 47 Belgrave Square, London, S.W.1.
Lecture: "A survey of eddy-current methods used in non-destructive testing."
By: R. Meakin.
Lecture: "Trends in American Radiology."
By: W. Binks.

Hon. Secretary: Dr. L. Mullins, Research Laboratory, Kodak Ltd., Harrow, Middlesex.

Electronics Group

Date: March 9. Time: 5.30 p.m.
Held at: The Institute of Physics, 47 Belgrave Square, London, S.W.1.
Group Annual Meeting followed by—
Lecture: "Comparison of Atomic and Nuclear Energy Levels."
By: H. A. Jahn, M.Sc., Ph.D.

Hon. Secretary: Dr. A. J. Maddock, "Sira," Southill Road, Elmstead Woods, Chislehurst, Kent.

Institution of Electronics

North-Western Section

Date: March 16. Time: 6.30 p.m.
Held at: Reynolds Hall, College of Technology, Manchester.
Lecture: "Microwave Telecommunications."
By: R. G. B. Gwyer, M.A.
Note: This meeting is open to Members and Members friends only.

Hon. Secretary: L. F. Berry, 105 Birch Avenue, Chadderton, Lancs.

The Television Society

Meetings will be held at The Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.

Constructors' Group

Date: March 10. Time: 6 p.m.
Lecture: "The Constructors' Group Vision Transmitter."
By: Members of the Sub-Committee.
To be followed by a Discussion.

Group Secretary: A. E. Sarson, 22 Union Road, Bromley, Kent.

Programme Group

Date: March 17. Time: 6 p.m.
Lecture: "Studio Design."
By: N. Q. Lawrence.
Note: The Annual General Meeting will be held at The Waldorf Hotel, Aldwych, London, W.C.2., on April 1, at 6 p.m. This will be followed by the Annual Dinner also at the Waldorf Hotel at 7 p.m. for 7.30 p.m.

Lecture Secretary: T. M. C. Lance, 35, Albemarle Road, Beckenham, Kent.

Royal Photographic Society of Great Britain

Scientific and Technical Group

Date: March 18. Time: 7 p.m.
Held at: 16 Princes Gate, London, S.W.7.
Symposium on—"Photography in Nuclear Research."
The Secretary, Royal Photographic Society of Great Britain, 16 Princes Gate, London, S.W.7.

Radio Society of Great Britain

All meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Date: March 12. Time: 6.30 p.m.
Lecture: "The Practical use of Frequency Modulation on Amateur Frequencies."
By: D. N. Corfield.

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

British Sound Recording Association

Date: March 11. Time: 5.45 p.m.
Held at: The Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2.
Lecture: "Loudspeakers—with particular reference to high-fidelity Monitoring Reproducers."
By: D. E. L. Shorter.
Note: This is a joint meeting with the Acoustics Group of the Physical Society.

Date: March 25. Time: 7.15 p.m.
Held at: E.M.I. Studios, 3 Abbey Road, St. Johns Wood, London, N.W.8.
Lecture: "High Quality Disk Recording."
By: W. S. Barrell.

Hon. Secretary: R. W. Lowden, Napoleon Avenue, Farnborough.

Brit. I.R.E.

London Section

Date: March 11. Time: 6 p.m.
Held at: The London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1.
Lecture: "The Principles and Practice of Panoramic Display."
By: D. W. Thomasson.

Publications Officer, 9 Bedford Square, London, W.C.1.

North-Eastern Section

Date: March 10. Time: 6 p.m.
Held at: Neville Hall, Westgate, Newcastle-on-Tyne.
Lecture: "The Calculation of Electrode Temperatures in the Radio Valve."
By: I. A. Harris.

Local Secretary: M. A. Boardman, 20 Princes Avenue, Gosforth.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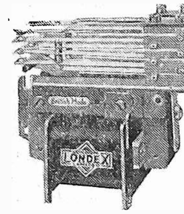

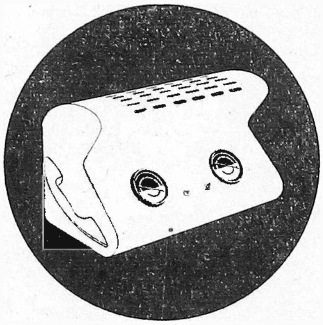

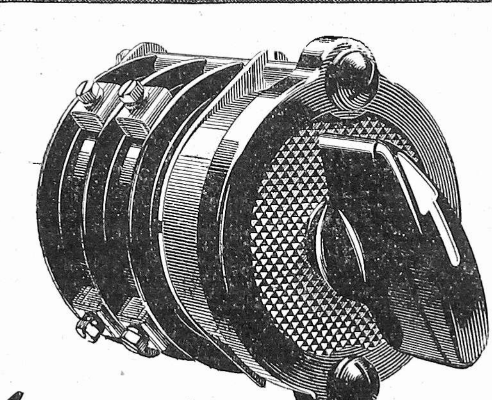

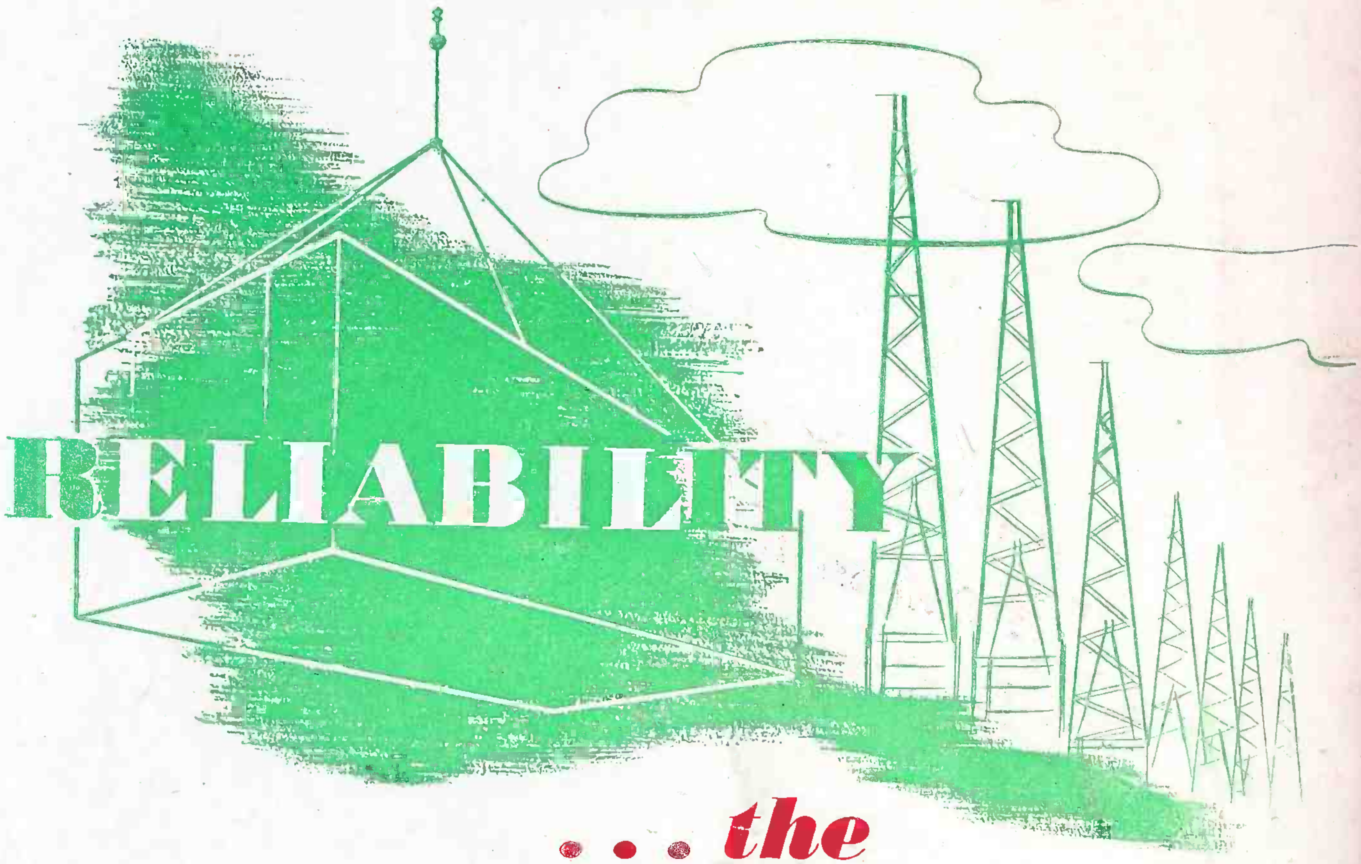

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