Electronic Engineering

Incorporating... ELECTRONICS, TELEVISION & SHORT WAVE WORLD

VOL. 20 No. 239 JANUARY 1948 PRICE 2/-

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.

OFFICIAL APPOINTMENTS

Vacancies advertised are restricted to persons or employments excepted from the provisions of the Control of Engagement Order, 1947.

THE AIR MINISTRY has vacancies in the Meteorological Office organisation for a number of civilian Radio (Meteorological) Mechanics to maintain radar equipment.

Applicants must possess a knowledge of the fundamental principles of radio and radar and practical experience in the maintenance and use of electrical, radio and radar instruments including cathode-ray oscilloscopes.

Preference will be given to former Royal Air Force personnel and any other ex-Servicemen possessing the requisite qualifications. Staff selected will be required to serve at any station at home or abroad and in the case of appointments at home units, will generally be expected to make their own arrangements for accommodation. Successful applicants will be engaged on a non-pensionable basis only, although prospects of later being placed on the permanent establishment are not ruled out. The commencing weekly wages in the United Kingdom are £6 5s. per week (inclusive) for appointees aged 21 and over. Varying allowances are payable in addition to the basic wage for service in most overseas locations.

Applications should be addressed to Air Ministry (S.5.(h)), Bush House, N.W. Wing, Aldwych, London, W.C.2.

UNIVERSITY OF ADELAIDE.

Department of Electrical Engineering.

B.B.C. invites applications to fill a vacancy in the Research Department of the Engineering Division. The work involves theoretical and practical investigations on aerials, transmitters, and systems of modulation. Practical experience of such work is desirable, but not essential. Applicants must possess recognised academic qualifications, including a knowledge of the theory of wave propagation, and an aptitude for original investigation. The salary is on a grade rising by annual increments of £25 to a maximum of £580 per annum; good promotion prospects. The successful candidate will be based at Oxford, but will later be transferred to a permanent base near London. Applications stating age, qualifications and experience should reach the Engineering Establishment Officer, Broadcasting House, London, W.1, within 14 days of the appearance of this advertisement.

Applications are invited for the position of **Lecturer in Electronics.** Applicants must be graduates in either science or engineering, and experience in development of radar, cathode ray oscillograph, and wide band receiving equipment, is desirable.

The salary range will be £600-£750 per annum (Aust.) according to qualifications and experience. The appointment will be for the period of rehabilitation training and in the first instance for three years. Further particulars may be obtained from the Secretary, Universities Bureau of the British Empire, 5 Park Street, London, W.1. Closing date for the receipt of applications is January 12th, 1948.

SITUATIONS VACANT

FERRANTI LIMITED require for Vacuum Physics Laboratory Physicists or Engineers, graduates or with equivalent qualifications, preferably with experience of electronic vacuum work or U.H.F. valves. Application forms from Personnel Manager, Ferranti Limited, Ferry Road Edinburgh, 5.

SENIOR ENGINEER required for development of radio components by progressive company in Surbiton area. Degree or equivalent in electrical engineering essential. Box 153, E.E.

LONDON APPOINTMENT offered to Assistant Physicist with a leaning to radio and electrical circuits. Applicants should have appropriate electrical qualifications and not less than two years experience, and will be required to develop the electrical aspects of physics evaluation in a large chemical manufacturing company. The work offers prospects for promotion. Commencing salary range £375-£500. Box 140. E.E.

ASSISTANT for light electrical apparatus test room Higher National Standard. Experience in insulation resistance and general electrical measurements essential. Full particulars of training and experience and state salary commensurate therewith. Siemens Brothers & Co. Ltd., Ref. 609, Woolwich, S.E.18.

RESEARCH AND DEVELOPMENT Assistants of H.N.C. or Intermediate standard for high vacuum equipment developments, covering electronic, instrument, physical and light mechanical engineering work. Progressive superannuated posts with opportunities for continued study. Salary commensurate with age, experience and qualifications. Apply with full details to W. Edwards & Co., (London) Ltd., Kangley Bridge Road, Lower Sydenham, London, S.E.26.

TEST GEAR MAINTENANCE Engineer required by radio manufacturers. Erith district. To take charge of calibration and standards. Previous experience essential. Apply Box 168, E.E.

RADIO MACHINE SHOP FOREMAN required to supervise the production of components for radar and radio equipments, Manchester area. Address particulars of age, experience, qualifications and salary required to Box 173, E.E.

APPLICATIONS ARE INVITED for position of chief planning engineer for large radar and electronic equipment company, north Manchester area. Must have good engineering background, be fully conversant with all machine shop, fitting, and assembly operations. Apply giving full details of age, experience, career and salary required to Box 178, E.E.

SUPERINTENDENT REQUIRED to take charge of radar and radio assembly department, large electronic equipment company, Manchester area. Must be capable of controlling male and female labour on track and bench assembly. Apply giving fullest particulars of age, experience, qualifications and salary required to Box 177, E.E.

MATHEMATICIAN required for design of electronic test gear by large manufacturer in east London area. Suitable applicants must have recognised qualifications in mathematics or pure science. State age, experience and salary required to Box 166, E.E.

JUNIOR ELECTRONIC ENGINEER with experience of sound recording required by design department for work in connection with new commercial product. Reply stating qualifications, experience, age and salary required to Box 164, E.E.

FERRANTI LIMITED have a vacancy for a research assistant on work connected with the development of cathode-ray tubes. He should possess an honours degree in physics or electronic engineering with industrial or university research experience involving knowledge of high vacuum work, thermionic emission and gas discharges. Direct acquaintance with development or manufacture of cathode-ray tubes would be an advantage. Application to the Staff Manager, Ferranti Limited, Hollinwood, Lancs.

TRANSFORMER DEPARTMENT SUPERINTENDENT required by radar and radio electronic equipment company, Manchester area, to take charge of modern transformer shop, must be fully conversant with all operations of coil winding, impregnation, and assembly by male and female labour. Address replies giving details of age, experience and salary required to Box 176, E.E.

SENIOR MICROWAVE ENGINEER and physicist required for important practical development work in a large industrial organisation in the south. Salary fully commensurate with qualifications and experience State full details of experience to Box 165, E.E.

REQUIRED, MACHINE SHOP SUPERINTENDENT by radar and radio manufacturers, large factory, Manchester area. Must be capable of controlling male and female labour engaged on production of components for assembly lines. Knowledge of machine, press and fitting operations essential. Apply giving full particulars of experience and salary, etc., to Box 175, E.E.

TECHNICIAN required to take complete charge of testing department for small manufacturer of electro-acoustic instruments. Work involves accuracy and close measurement. Will be required to assist with instrumentation and construction of test equipment. Wembley district. Box 170, E.E.

CONTACT SOUGHT with specialist able to advise occasionally on R.F. transmission line problems. Box 172, E.E.

PRODUCTION-MINDED TESTER required to take charge of small sub-section engaged on repetition work, electro-acoustic instruments. Wembley district. Box 171, E.E.

RADIO SENIOR ASSEMBLY FOREMAN required, Manchester area, must be capable of controlling male and female labour, experience in assembly beltd lay-out and familiar with A.I.D. requirements. Apply stating age, experience and salary required to Box 167, E.E.

RADIO COMMUNICATIONS Equipment. Physicist or engineer is 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 stating age, experience and qualifications to the Director, Research Laboratories of the General Electric Co., Ltd., North Wembley, Middlesex.

PLANNING ENGINEERS required by light engineering company, north Manchester area, accustomed to radar and radio equipment production. Must have served general engineering apprenticeship and be capable of developing and planning all machine shop, fitting and assembly operations. Apply stating age, experience and salary required to Box 180, E.E.

ENGINEER required for laboratory investigation and measurements in conjunction with radio and electronic devices. Experience in electron optics desirable, with ability for original design. Applicants should have reached accepted standard of education and carry adequate production-design experience. West Middlesex area. Apply giving age, full details of education and experience to Box 179, E.E.

REQUIRED, experienced male estimating engineers with good engineering background and capable of producing accurate precalculated factory costs of radio receivers and similar products. Good salary for men with the right qualifications. Apply in writing with full details to Works Personnel Officer, Mitcham Works Limited, New Road, Mitcham Junction, Surrey, quoting reference B. 3.

REQUIRED—EXPERIENCED ESTIMATORS capable of producing accurate precalculated factory costs of transmitting valves and industrial rectifiers, etc. Good salary to men with the right background. Apply in writing, with full details to Works Personnel Officer, Mullard Radio Valve Co., Ltd., New Road, Mitcham Junction, Surrey, quoting reference B. 3.

ST. DUNSTAN'S requires an assistant for research work in connexion with sound recording and other electronic aids for blind people. Applicants should have an Honours Degree in physics and/or communications engineering, preferably with practical experience in this branch of electronics. Initial salary according to qualifications in the region of £450-£550 with superannuation under F.S.S.U. Apply to St. Dunstan's Research Department, 8, Hinde Street, Manchester Square, W.1.

EXPERIENCED DESIGNER of fractional h.p. motors required by large company in the east London area. Applicants must possess qualifications to cover completely both practical and technical design of universal and induction type motors. State full details of experience, qualifications, age and salary to Box 182, E.E.

SITUATIONS WANTED

EX-SIGNALS OFFICER (Advanced Wireless Course, Catterick; 4 years overseas experience organising long-range transmitters, receivers) pre-war Maths. undergraduate unable resume this year, seeks opening home or abroad. Communications, recording, television preferred. Sound technical background, 12 years amateur radio and television enthusiast. Box 184, E.E.

GENERAL MANAGER, fully experienced to control works and sales, electronic, electrical or mechanical products. 15 years with two well-known firms. Hons.B.Sc. (Eng.), A.M.I.E.E. 39. Free now. Extremely adaptable. Box 181, E.E.

EDUCATIONAL

SPEECH DISABILITY: Mr. H. V. Hemery consults at Wigmore Hall Studios, Wigmore Street, W.1.

INDEX TO ADVERTISERS

SEE **PAGE 28**

CLASSIFIED ANNOUNCEMENTS (Cont'd.)

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.

A.M.I.E.E. Examinations. Electrical engineer-lecturer (B.Sc. Eng. Hons. A.M.I.E.E.) specialises in private individual tuition. Vacancies for October 1948 exam. Personal or correspondence. Box 147, E.E.

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, S.W.7.
ELECTRICAL ENGINEERING DEPARTMENT

A COURSE OF EIGHT LECTURES
by
DR. J. A. SAXTON,
Radio Division, National Physical Laboratory
on
RADIO WAVE PROPAGATION
will be given on
Mondays at 4 p.m., commencing on **19th January**, 1948.

The course will cover: ground wave transmission; structure of the ionosphere and its effect on propagation; tropospheric phenomena at very high frequencies.

NOTICE REGARDING FEES AND ADMISSION. Application for admission should be made to the Deputy Registrar, City & Guilds College, Exhibition Road, S.W.7. The fee will be £2 2s. for the course of eight lectures. Students of the college and inter-collegiate students will be admitted free to the lectures, the latter on production of an inter-collegiate ticket.

FOR SALE

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.

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 146, E.E.

2" THERMOCOUPLE MOVING COIL MILLI-AMMETERS. 0-350 m/a. New ex-Gov. A bargain at 5/6 each. £3 per dozen, post tree. S. McMillan, 5 Oakfield Road, Bristol, 8.

FURZEHILL DIODE VOLTMETER 281B. Scarcely used. £35. Really fine bargain. FSR., 87a Upper Richmond Road, S.W.15.

V.H.F. SUPERHET RECEIVER ex-A.M., 9 valves including B.F.O. Covers two new bands 130-520 megacycles, unused with diagram. Power pack needed. Exchange general coverage communications receiver or cash. Box 183, E.E.

0-100 MICRO-AMP. moving coil meters, by reputable manufacturer. Surplus stock, cheap to clear. Box 162, E.E.

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.

FOR DISPOSAL surplus to requirements—1,500 Sunvic Thermal type adjustable (15 to 90 seconds) delay relays model TYE, having single pole, 5-amp. 23-volt. Normally open contact and heater wound for 220/230 volts. Price for quantities upon application. Box 160, E.E.

VACUUM TANK CONDENSERS 50pF, 5000 v 7s. 6d., variacs, behind-panel mounting, 0-70v. 7 amps. 35s. 238-254 Mc/s Homing Adaptor, four 954 acorns, circuit supplied, 30s. Carriage extra. Brown, 37 The Chesils, Coventry.

WANTED

WANTED—D.C. or A.C./D.C. turntable. State particulars and price to Gabb, 16, Augusta Road, Moseley, Birmingham 13.

NEW 12-inch magnetic cathode-ray tube urgently required. Any make. E. T. Hall, Ewelme Park, Henley-on-Thames.

COIL UNITS for Eddystone 358 receiver, ranges S.4. medium and long. Box 185, E.E.

SERVICE

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.

LET US DESIGN or make to your needs television scan coils, blocking oscillator or line output transformers. Enquiries invited. Box 169, E.E.

SMALL FIRM has capacity for manufacturing radio chassis, metal cabinets and metal fittings. Presswork a speciality. Individual or quantity orders. Box 174, 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.

PHOTOGRAPHY BY BEHR will show your product at its best. Ask for illustrated list. 44, Temple Fortune Lane, London, N.W.11. SPEedwell 4298.

ARE YOU INTERESTED in reproducing sound as nearly as possible to the original and doing this at a reasonable cost? If so, we invite you either to come to our demonstrations or write for full particulars. Demonstrations daily 9.30—10.30 a.m., 6—6.30 p.m. excepting Saturdays. Rogers Developments Co., 12, Macclesfield Street, Shaftesbury Avenue, W.1.

SUPPLIERS of high grade radio components including television and high fidelity radio equipment. All types of radio and electronic apparatus built to your specification. Large stocks of close tolerance resistors. Rogers Developments Co., 12, Macclesfield Street, W.1.

S.H.E.F.I. MOVING COIL PICK-UP is now available for both home trade and export. It combines for the first time high fidelity with high output voltage, enabling it directly to replace normal moving iron pick-ups without any extra amplification. It has an exceptionally clean response with no undesirable resonances, thereby reducing needle scratch. Retail price including transformer 40/- plus 8/11 purchase tax. Wholesale and retail enquiries invited. Illustration sent on request. Brooks and Bohm Ltd., 90, Victoria Street, S.W.1.

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.

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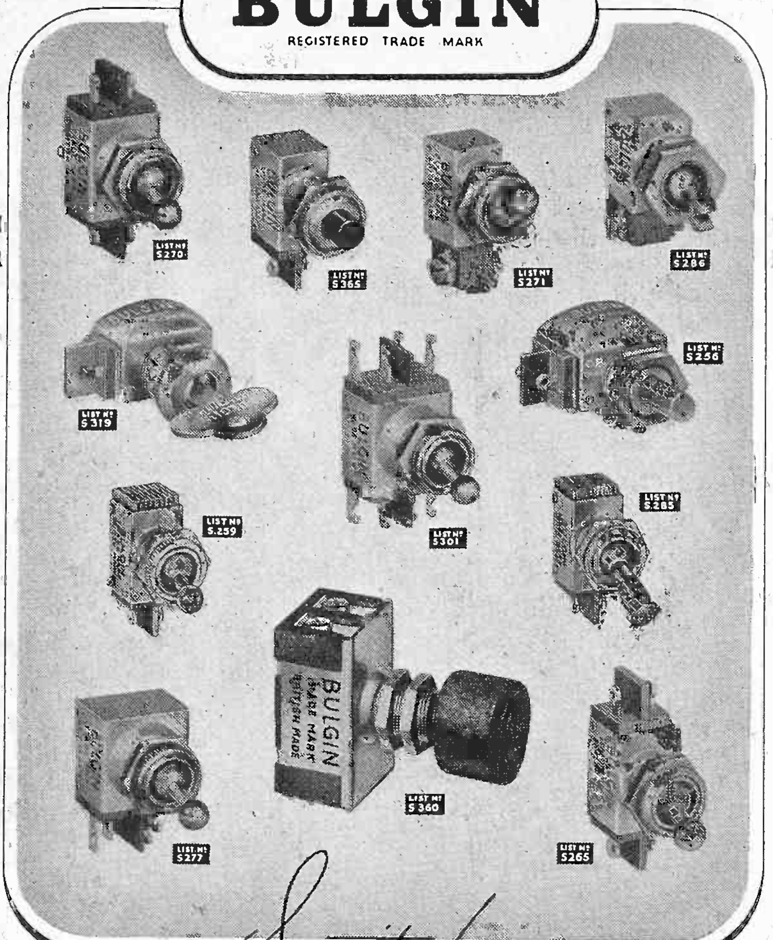

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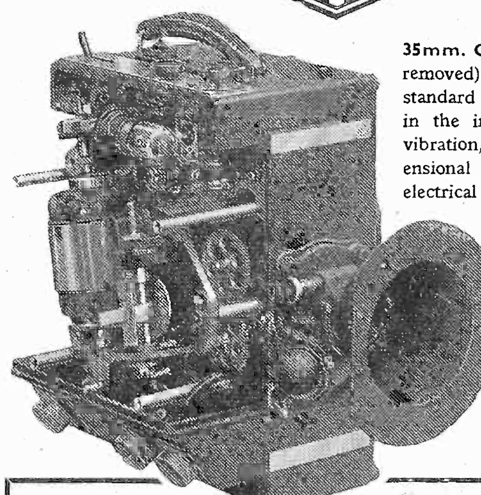

35mm. Camera (cover removed). Used with standard oscillograph, in the investigation of vibration, stresses, dimensional variations and electrical phenomena.

Design, Development and Manufacture of Optical Mechanical Electrical Instruments

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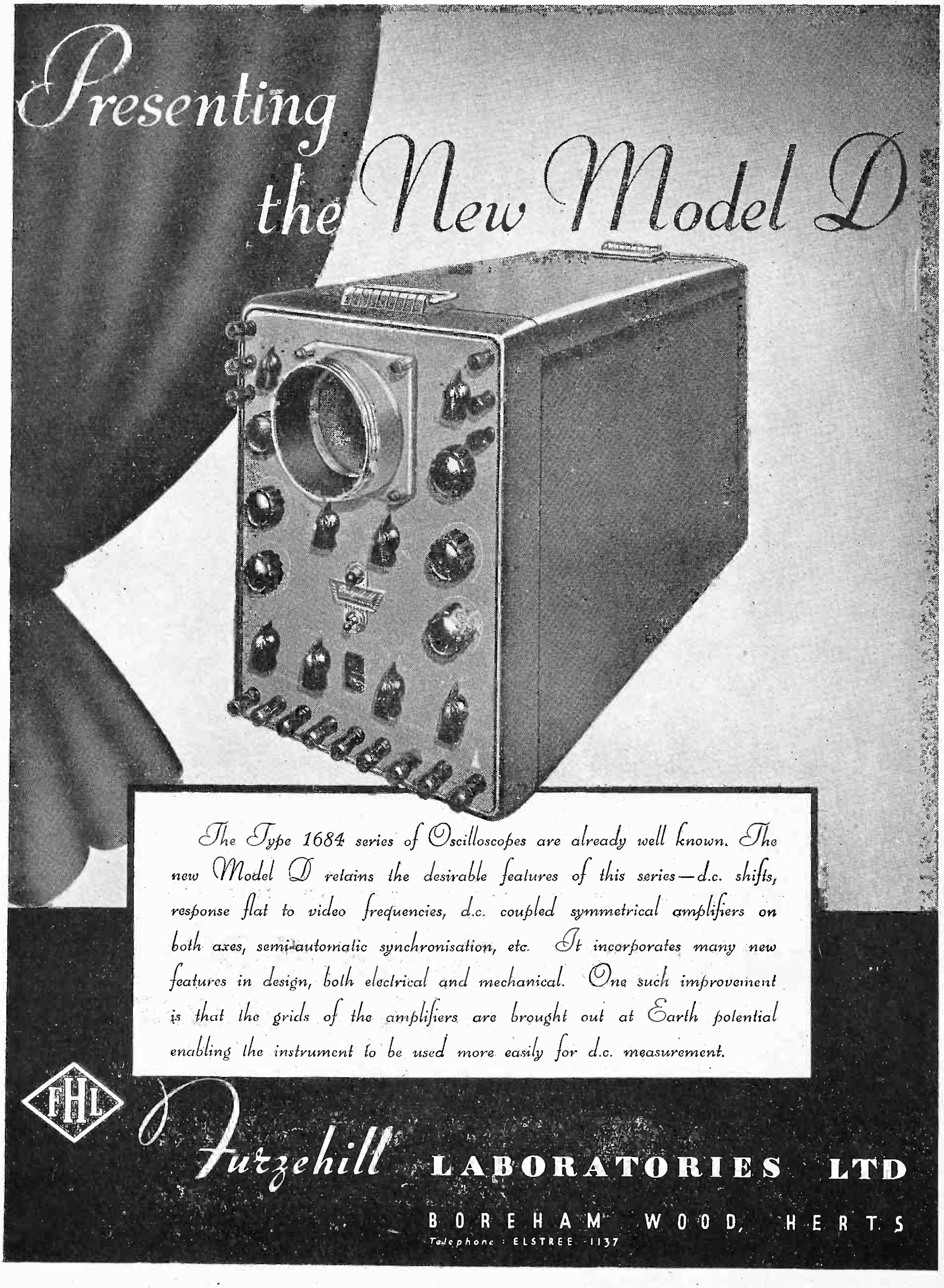
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The Type 1684 series of Oscilloscopes are already well known. The new Model D retains the desirable features of this series—d.c. shifts, response flat to video frequencies, d.c. coupled symmetrical amplifiers on both axes, semi-automatic synchronisation, etc. It incorporates many new features in design, both electrical and mechanical. One such improvement is that the grids of the amplifiers are brought out at Earth potential enabling the instrument to be used more easily for d.c. measurement.
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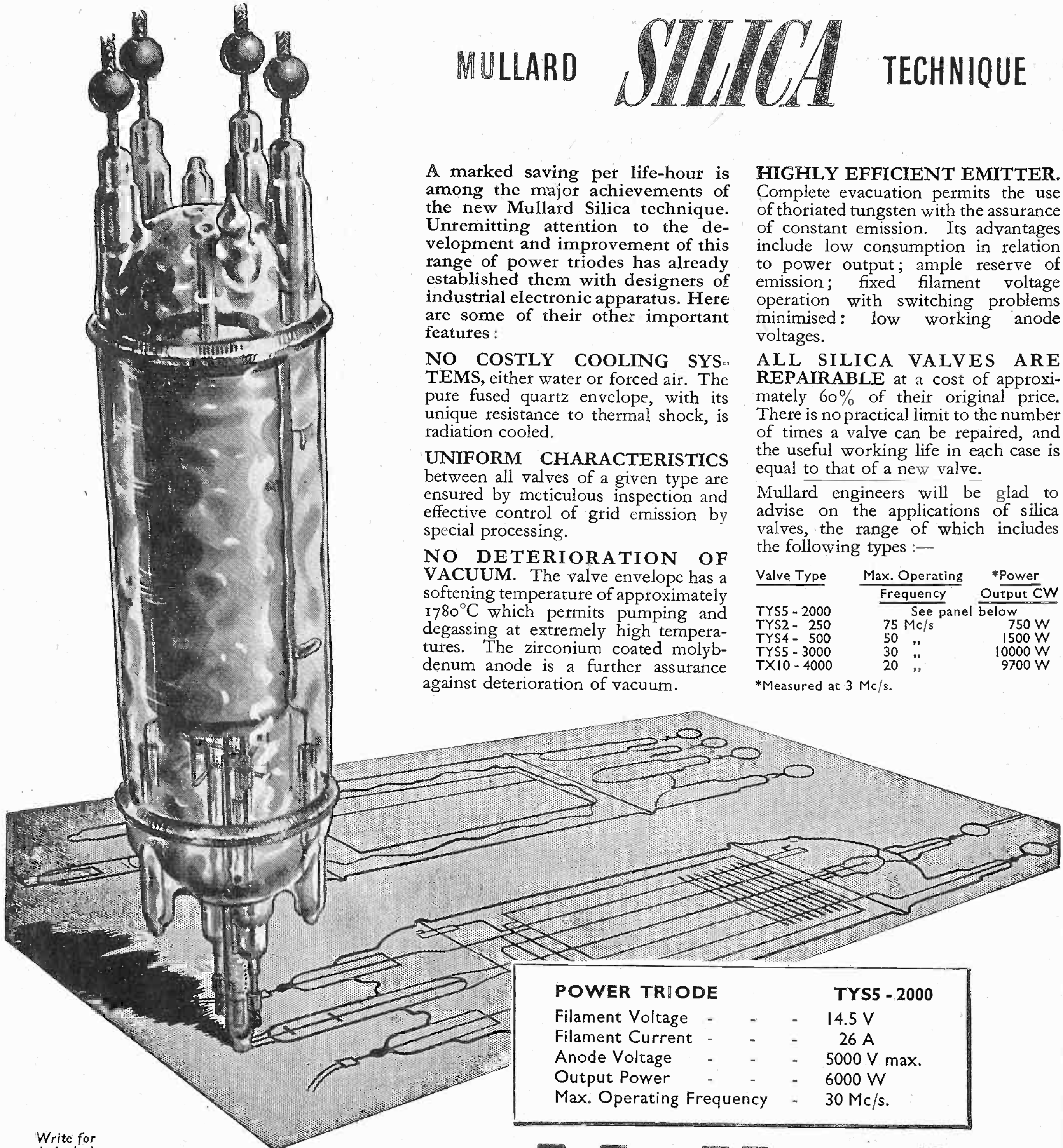

A marked saving per life-hour is among the major achievements of the new Mullard Silica technique. Unremitting attention to the development and improvement of this range of power triodes has already established them with designers of industrial electronic apparatus. Here are some of their other important features:

NO COSTLY COOLING SYSTEMS, either water or forced air. The pure fused quartz envelope, with its unique resistance to thermal shock, is radiation cooled.

UNIFORM CHARACTERISTICS between all valves of a given type are ensured by meticulous inspection and effective control of grid emission by special processing.

NO DETERIORATION OF VACUUM. The valve envelope has a softening temperature of approximately 1780°C which permits pumping and degassing at extremely high temperatures. The zirconium coated molybdenum anode is a further assurance against deterioration of vacuum.

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ALL SILICA VALVES ARE REPAIRABLE at a cost of approximately 60% of their original price. There is no practical limit to the number of times a valve can be repaired, and the useful working life in each case is equal to that of a new valve.

Mullard engineers will be glad to advise on the applications of silica valves, the range of which includes the following types :—

Valve Type	Max. Operating Frequency	*Power Output CW
TYS5 - 2000	See panel below	
TYS2 - 250	75 Mc/s	750 W
TYS4 - 500	50 ,,	1500 W
TYS5 - 3000	30 ,,	10000 W
TX10 - 4000	20 ,,	9700 W

*Measured at 3 Mc/s.

POWER TRIODE	TYS5 - 2000
Filament Voltage - - -	14.5 V
Filament Current - - -	26 A
Anode Voltage - - -	5000 V max.
Output Power - - -	6000 W
Max. Operating Frequency -	30 Mc/s.

Write for technical data on these and other Mullard valves.

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MVT 17

Electronic Engineering

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

[TE]LEPHONE: CENTRAL 6565 (10 LINES) MANAGING EDITOR G. PARR, M.I.E.E. TELEGRAMS: LECTRONING, ESTRAND, LONDON

Monthly (published last Friday of preceding month) 2/- net. Subscription Rate: Post Paid 12 months 26/-.

Vol. 20. No. 239 January, 1948

CONTENTS

Information

THIS issue commences a new volume of this Journal—No. 20—and an opportunity has been taken to make a number of changes, one major and several minor, which it is hoped will improve its appearance and value.

The type face has been altered throughout to give greater legibility, while permitting the same amount of matter to be fitted on the page. The articles have been separated from the advertising matter as far as convenient — an arrangement which will receive general approval, to judge from various comments which have been made from time to time. In making this change, we are confident that our advertisers will not suffer any disadvantage. The view has always been held that in technical literature the advertisements are read with the same interest as the text matter, and it is hoped that they will be found equally informative.

The Classified Announcements are now at the beginning of the issue and not at the end, and for the convenience of inquirers an index of advertisers is now added on the last page.

There are other small points which will be evident to the assiduous reader, and although no prize is awarded for spotting them, we would welcome any comments or criticisms which the alterations provoke.

Further notes for new readers are:

Back Copies

Before applying for back copies, please inquire whether they are available. This will save the staff time and trouble in returning money sent if the copies are not in stock. If a "want list" is sent in, the reader will be notified when copies become available.

The Circulation Dept. will be pleased to hear from readers who have back copies in good condition for disposal. Please send full details of year, date, etc.

Monographs

The following monographs are still available at the prices quoted:

Frequency Modulation (3rd Edition)	2s. 8d.
Plastics in Radio	2s. 8d.
Photocells in Industry	3s. 3d.

"The Electron Microscope" is at present reprinting in a second revised edition, and will be available shortly, price 4s. 9d. All prices include postage.

"Televisor" Booklet

The first large printing of this booklet is now exhausted and a second printing is in hand. It is expected that supplies will be available before the end of this month, and readers who have sent in orders are asked to be patient a little longer. The second printing includes some amendments and corrections which have been pointed out by constructors, and a list of these appears on p. 25 of this issue. Owners of the early copies are asked to note these amendments in their texts.

"The Synchrodyne"

This original receiver design was first described in the March, 1947 issue, and further details appeared in the August and September issues. Its success, when exhibited at Radiolympia, took us a little by surprise and there has been a slight delay in publishing further details, including those of the construction.

Another article by the designers will be published in next month's issue, which will also contain a full circuit diagram of the "senior" and "junior" models.

A limited number of complete reprints of the original articles are still available from the Circulation Dept., price 2s. 2d. post free.

A Mobile X-Ray Unit

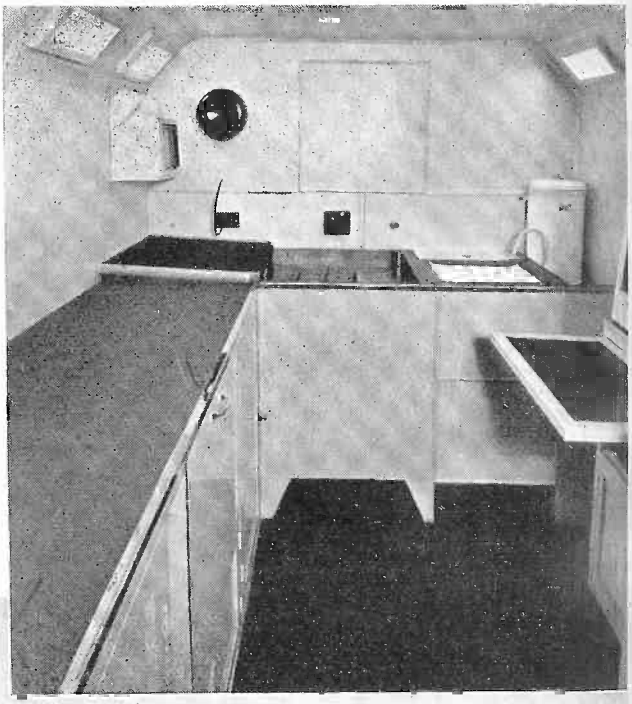
THE problem of the satisfactory X-ray examination *in situ* of welded high pressure pipe lines has been solved by the production of a fully mobile unit shown in the photographs.

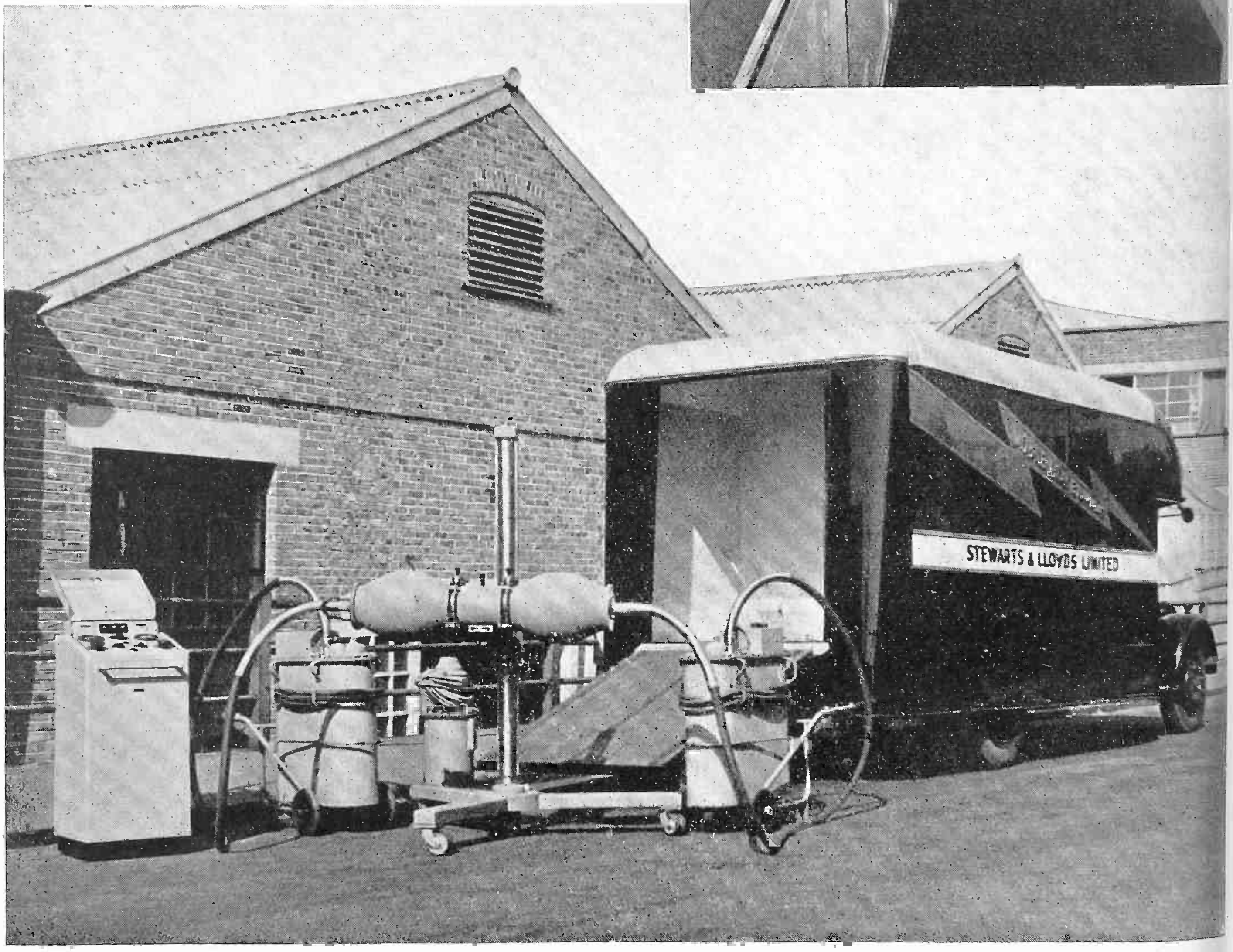
It is housed in a four-ton van, the body of which is divided into compartments to accommodate the equipment and provide the necessary dark room service.

In the dark-room (shown on the right) is a special film-loading bench, processing unit and wash basin, viewing lantern, and quick-drying facilities.

The X-ray unit is a Philips Macro 300 inspection unit capable of examining steel up to $4\frac{1}{8}$ in. thick., and is supplied from two generators on small wheeled trollies. Special cable and hose drums are housed in compartments below the chassis and a 34-gall. storage tank is above the driver's cabin to boost the water pressure.

The equipment was designed by Philips Electrical Ltd., for Stewarts & Lloyds, one of the largest metal tube manufacturers in the country, and will be used for routine examination of the pipe lines after laying. It should be of equal interest to shipbuilders and constructional engineers whose problems involve examination *in situ*, as the search for dark-room accommodation often wastes time and trouble even when no difficulty is found in making the examination.





High Vacuum Pumps — Their History and Development

Part I — Early Types

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

THE extensive use of high vacuum equipment suitable for pressure reductions to less than, say, 10^{-5} atmospheres was initiated by the requirements of the incandescent lamp industry and was then accentuated by the development of electronic valves, X-ray tubes, rectifiers, photo-cells and the like. Only in recent years new applications have been rapidly developed, especially under the pressure of war needs, and mainly in the fields of chemical and metallurgical engineering, in the surface treatment of optical glasses, in the metallising of mirrors, in the dehydration of foodstuffs, the separation of vitamins, the preparation of plasma for blood transfusion and the large-scale manufacture of penicillin. Also in the production of the atomic bomb high vacuum processes have played their part, especially in the separation of isotopes. For the cyclotron and other accelerators, so important in the study of nuclear physics, a high vacuum is required.

Some general remarks made in a previous article[23] will not be repeated here, although they refer to vacuum pumps as well as to vacuum gauges. This is especially the case regarding the units used in vacuum technique, the pressures used in various apparatus, the vapour pressures of various substances and—at least in some of the pumps—the significance of the mean free path of the molecules. The interested reader is referred to the previous article.

In dealing with high vacuum pumps we are not only concerned with the ultimate pressures obtainable by any kind of pump, but also with the special conditions necessary for obtaining these low pressures, *e.g.*, the state from which pumping is started, be it atmospheric pressure or the pressure of a preliminary vacuum or fore-vacuum. We are also interested in the speed of evacuation, the quantity removed in unit time, this quantity being usually a function of pressure.

As was the case with high vacuum gauges, also here the quality of the vapour or gas to be exhausted frequently plays an important part and so does the size, shape and state of the inner surface of the vessels and the connecting tubing, the purity of the mercury or oil used as working fluids and so on.

Also here we shall confine ourselves to the most important types of pumps and to those applicable to pressures of 10^{-1} mm. Hg and less. Besides, we shall generally not deal with what Andrade[24] calls "mural" pumps, *i.e.*, those appliances which are based on chemical action, sorption processes, "gettering" and the like.

Historical

From antiquity to the end of the 17th Century

While the development of accurate measuring methods and appliances for vacua did not start before the middle of the 17th century we have to go further back when dealing with vacuum pumps. The question whether or not empty space exists at all has played an important part in philosophical speculation since it was affirmed by the first "atomists," Leucippos of Miletos and his disciple Democritos in the 5th and 4th century, B.C. Aristotle's view of the non-existence of empty space, based on the sentence "non entis non sunt differentiae" (the non-existing has no distinguishing features) led to the long cherished notion of the "horror vacui" although the very expression "horror vacui," was apparently not used in this form before Galilei applied it for explaining the fact that water cannot be lifted higher than about 30 ft. by a suction pump. Popular books of quotation attribute the sentence "natura abhorret vacuum" (nature abhors empty space) to Rabelais (1483-1553). In fact, he tells how, when his hero Gargantua is about to be born, the father invites his friends to a drinking bout in order to console himself for the pains his wife has to suffer. He shouts to them across the table "Fill your glasses up to the brim. Natura abhorret vacuum." But it is quite apparent that Rabelais quotes from an older author. This seems to be Albert of Saxony (1316-1390),[25] a scholastic divine and philosopher who, after lecturing at the University of Paris, became the first rector of Vienna University and died as bishop of Halberstadt.

The question why water cannot fall from a vessel closed at its top and open at its bottom was much discussed by the scholastics. According to Thorndike[26] "writers before Roger Bacon" (1214-1294) "explained it by saying that the fall of the water would produce a vacuum and that a vacuum cannot exist in nature. Bacon argues a vacuum cannot be the reason why the water does not fall because a vacuum does not exist. He explains the phenomenon by the universal continuity of nature."

The death blow to the notion of the "horror vacui" was struck by Pascal[27] (1623-1662) who, after getting acquainted with Toricelli's experiments, made his own classical experiments on the Puits de Dôme, proving that not the "horror vacui" but the weight of the atmosphere is the cause of all the phenomena previously attributed to the former. His views were lively attacked by Father Etienne Noël who based his arguments on the Aristotelian view of the non-existence of empty space. Crude as the objections of Father Noël may be, they certainly contain a grain of what is to-day believed to be true. Pascal had expressed the view that the empty space in Toricelli's experiments in no way contains either particles of air passed through the pores of the tube or particles of mercury vapour. Father Noël objected to this view. As was mentioned in the previous paper, even with a pressure as low as 10^{-7} mm. Hg molecules of the order of 10^9 are still left in the cubic centimetre.

The principal objection raised by Pascal against the notion of the horror vacui was that to attribute human feelings to nature was unphilosophical and absurd.

But we are here less concerned with philosophical speculations than with actual methods and means for producing vacua. And to find the first published origins of such we have to go back to antiquity again. Hero of Alexandria (285-222, B.C.) describes in his "Spiritalia"[28] two appliances mainly used for surgical purposes which may be considered as the ancestors of some of the pneumatic machinery used later by Guericke, Boyle and their successors up to the present date. He calls them "pyulcus" and "smerisma." The pyulcus (Fig. 1) may be considered as the ancestor of the syringe and the piston pump and the smerisma as that of the valves, stopcocks and the like used in connexion with such pumps. But Hero shows the use of the smerismata, which, literally translated, mean ground-in tubes, in combination with a "cucurbitula," *i.e.*, with a cupping glass (Fig. 2). The exhaustion of such a cupping glass was not accomplished by a mechanical apparatus, but by the human mouth and tongue, the oldest "piston pump" and still very profusely used. The chest may be considered also as a "vacuum pump," though not based on the piston principle but on the bellows principle. In fact, in the modern "iron lung" bellows are used which take upon them the work usually done by the muscles of chest and diaphragm.

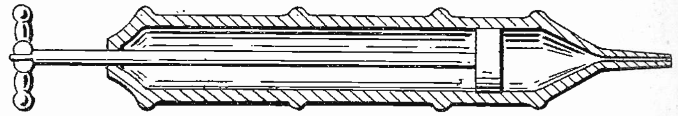
After Hero's time there followed a long pause in the further development during medieval times, when "philosophers dedicated themselves to abstract and useless questions instead of exploring nature by experiments and observations."[29]

Galilei, as we saw, still used the horror vacui as an explanation, yet "his first thought was that the horror vacui possessed a measurable power. He sought, moreover, to determine directly the weight able to draw out of a closed pump-barrel a tightly-fitting piston, resting on the bottom."[30]

His disciple, Toricelli, in his experiments of 1643, replacing the water column by the more easily manageable mercury column, laid the foundation for most of the further development.

It was Otto von Guericke who, with full knowledge of Toricelli's work, added two valves to the syringe described by Hero. The first description of his pump is contained in P. Gaspar Schott's

Fig. 1. Hero's syringe ("Pyulcus")



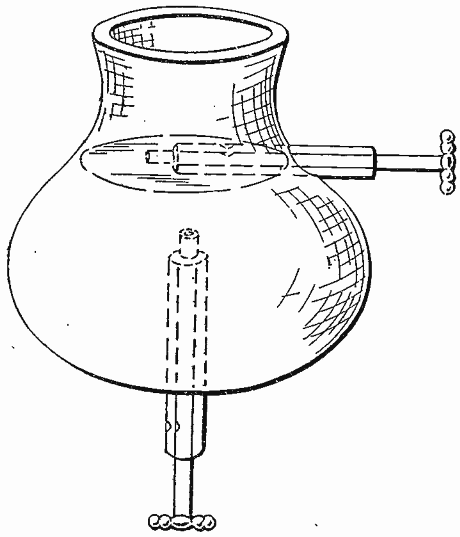


Fig. 2. Hero's cupping glass with stop cocks ("Cucurbitula" and "Smerismata")

"Mechanica Hydraulico - Pneumatica," published 1657 at Würzburg. Guericke had given his consent to this publication, while his own treatise, the "Experimenta nova," appeared as late as 1672. Meanwhile, Robert Boyle had started his experiments based on the knowledge of Schott's book. He had in collaboration with Robert Hooke improved Guericke's pump. Schott describes the operation of Guericke's pump with the words: "Duo validissimi viri arrepto manubrio, cum liguculis, agitant antliam extrahendo atque intrudendo pistillum" ("two very strong men operate the pump, tearing at the handle by means of ropes and extracting and intruding the piston)—in the illustration the two very strong men are replaced by two lovely little angels. In Boyle's design the operation is made more convenient by the use of rack and pinion. The addition of what we call to-day a bell jar with base plate was due to Huyghens and Papin, the latter assisting Boyle for some time in his experimental work. Guericke's later pumps as described in his "Experimenta nova" show that he used Boyle's experiences to some extent.

18th and 19th Century

In the further history of vacuum pumps till the end of the 19th century two lines of development may be noticed, although a strict line of demarcation cannot always be drawn. It became usual to discern between three kinds of vacua.

(1) The Toricellian or barometric vacuum, obtaining in the space between the top of the mercury column and the end of the closed tube.

(2) The Guerickian or Boylean or pneumatic vacuum produced by a pneumatic machine.

(3) The absolute vacuum or simply vacuum, *i.e.*, a space supposed to be empty of any matter or—in the words of Pascal—"empty of all bodies touching the senses." It may safely be said that this latter has so far been experienced. It is an abstraction similar to the absolute zero of temperature or the dimensionless point of the mathematician.

There remain therefore the two principles, the barometric and the pneumatic, to be considered in the further development of the pumps. In the early experiments of Toricelli and the other Florentine scientists of the Academia del Cimento a separate recipient was not used and if it was necessary to experiment with apparatus, requiring a larger space to be evacuated as in the first abortive test for investigating the propagation of sound in vacuo, they used Boyle's pneumatic pump "because it may be too hard a task, if not impossible, to place such instrument (an organ pipe) in a *Vacuum* made with mercury."[31] It was as late as 1722 that Swedenborg, the Swedish divine and philosopher, showed that a larger recipient may be evacuated by repeatedly lowering and lifting a separate vessel or tube connected to the recipient by a flexible leather hose.

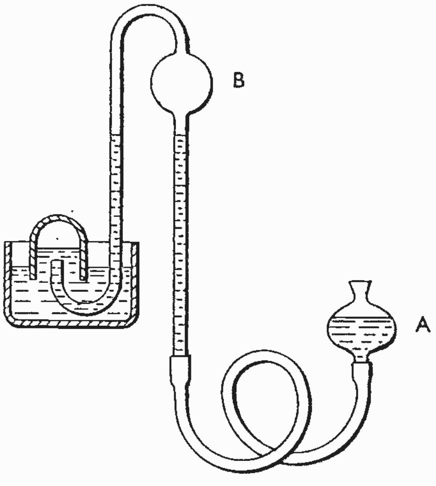
The development of this first "mercurial air pump" to what is known to-day as the Toepler pump will not be dealt with in detail here as there exists a very valuable monograph by S. P. Thompson, based on a paper read before the

Society of Arts in 1888, which gives an exhaustive history of this development.[32] Only a few points can be mentioned. This type of pump was to a large extent used by Geissler for the exhaustion of his discharge tubes and he also improved it by arranging special cocks reducing the dead space. A further improvement was proposed by T. R. Robinson and by Poggendorff[33] which did away with the mercury filled flexible leather or rubber tubing. Using the barometrical pump as final pump and a pneumatic one as fore pump, the raising and lowering of the mercury in the barometrical pump is effected without the mercury coming into contact with the flexible tube and thus the bad effect of aged tubing is avoided. Besides the necessary length of the barometric tube is considerably reduced. This arrangement seems also to be the first use of fore-and fine-pump which in modern high vacuum pumping equipment has become standard practice.

The improvement made by Toepler[34] consisted in the replacement of the cocks or valves necessary in the Swedenborg and Geissler designs by a mercury seal which allows the air to leave the pump and prevents it from reentering. Its principle is shown in Fig. 3. The tedious raising and lowering of the reservoirs A may be avoided by connecting the vessels A and B rigidly and transferring the Hg pneumatically from A to B.—In a more modern design due to V. Reden[35] the transfer of the Hg from one vessel to the other is effected by a rocking movement or both vessels may be combined in a rotating system of spiral tubes (Kaufmann[36]). All three designs are now mainly of historical interest. But it may be mentioned that Toepler's arrangement is still used to-day for collecting gases pumped out by more modern types of high vacuum pumps.[37-38] The pressure of the gas thus collected may afterwards be raised to atmospheric pressure and the gas transferred to a burette for being analysed. It has been stated that in this kind of pump the mercury acts like the piston of a barrel pump.

The ultimate pressure obtainable by a modern Toepler pump with Hg vapour frozen out is 10^{-5} mm. Hg. But it takes several hours to reach such a low pressure.

A quicker working was obtained by replacing the hydrostatic principle used in the Toepler pump by the hydrodynamic principle as proposed by Sprengel[39] who carried out his experiments at St. Bartholomew's Hospital. A narrow tube is used down which droplets of Hg flow, carrying with them the gas from the recipient (Fig. 4). The falling drops act like little liquid pistons. The action is more continuous and automatic than in the Toepler pump. But the volumetric



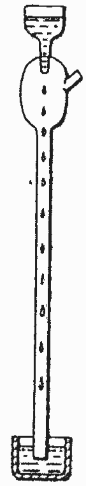


Fig. 3 (*above*). Toepler's pump

Fig. 4 (*above — right*). Sprengel's pump

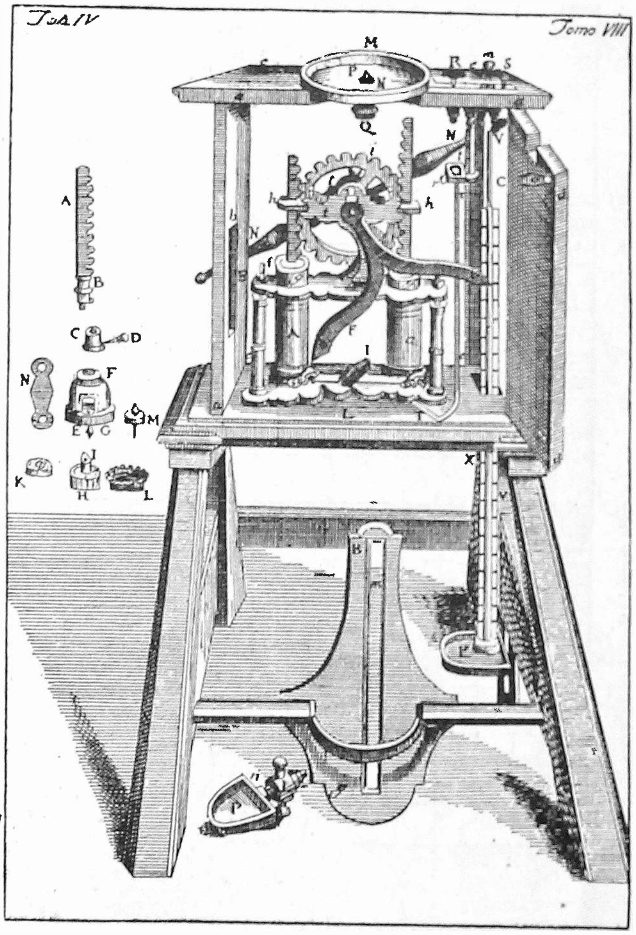


Fig. 5. Mechanical pump, 18th century

(*Table IV, De Turre, Elementa Physicae, 8th Vol.*)

speed is still very small, only a few $mm^3/sec.$ with a single fall pump. Therefore multiple fall pumps were designed in which several capillaries were arranged in parallel. In order to shorten the capillaries the Sprengel pump may be operated in combination with a fore-pump of the mechanical or water jet type and the fore-vacuum may also be used for lifting the Hg from the lower to the upper vessel. Numerous designs have been devised for this purpose, especially during the last decades of the 19th and the first decades of this century when Sprengel pumps were extensively used for the evacuation of incandescent lamps. But as they may now be considered as obsolete no further details shall be given here and the interested reader will find detailed descriptions in monographs about lamp manufacture.[40]

As to the pneumatic machines based on Guericke's and Boyle's designs the principal improvements made in the 18th century consisted in using double-barrel pumps as proposed by Hauksbee[41] and in actuating the valves positively by some kind of a lever mechanism. Such a pump is illustrated in Fig. 5.[42] Benjamin Martin describes in his "Philosophia Britannica," Reading, 1747, the double-barrel air pump and illustrates his own simplified design in which the two barrels and the recipient are arranged on the same bedplate. Somewhat boastfully he states: "I take this to be the last improvement this machine is capable of as to its form; for it consists of only such Parts as are Essential." More valuable than his design appear to be two tables derived from a simple logarithmic calculation, the first one giving the "rarefaction" obtainable with a given number of strokes of the pump if the cylinder volume is equal to the volume of the recipient, and the second one a factor with which this number of strokes must be multiplied to obtain a certain rarefaction if the ratio between volume of recipient and volume of cylinder is larger than unity. Fig. 6 combines the values of the two tables and gives the required number of strokes for a certain pressure. Of course, this is only of theoretical value as it applies only to permanent gases and the effects of vapours, of leaks and of dead space are neglected. But it shows that for obtaining absolute vacuum, i.e., infinite large rarefaction, an infinite large number of strokes is required.

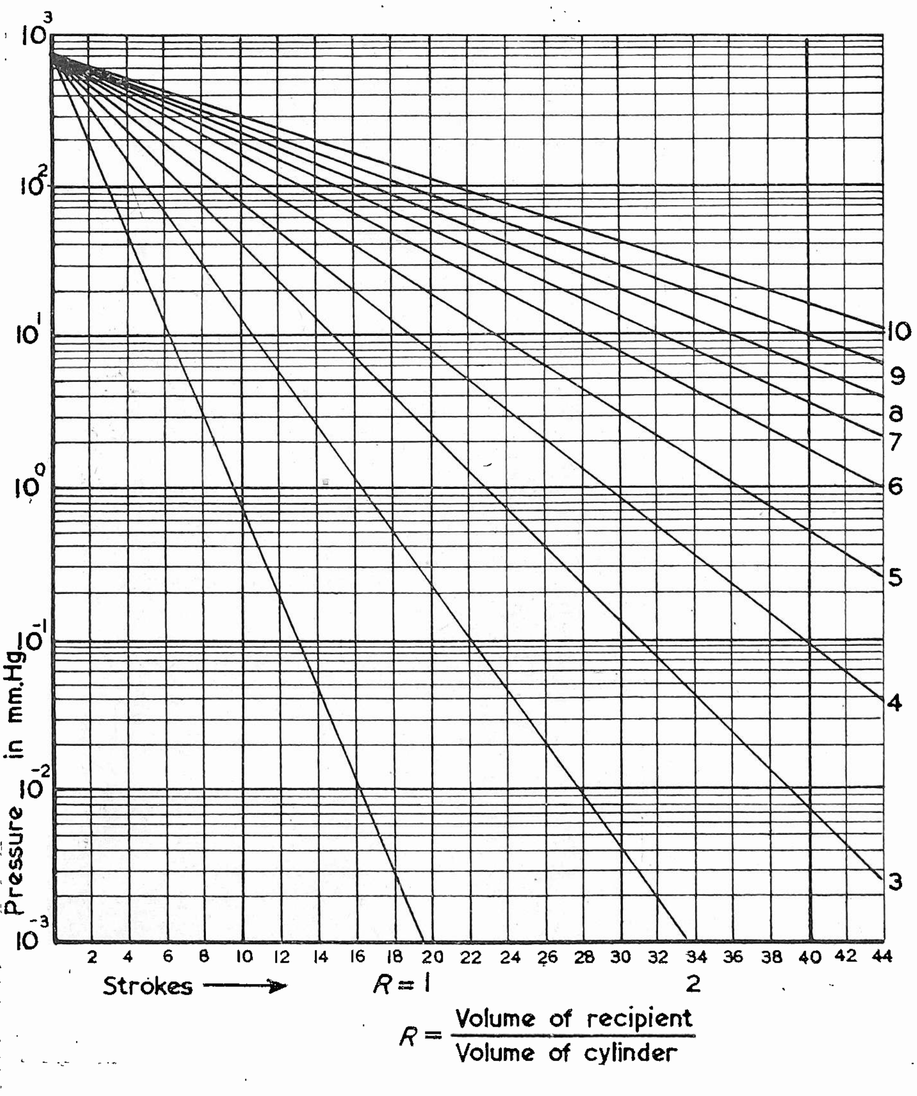


Fig. 6. Theoretical speed curve of mechanical pump

In the further development of vacuum pumps of the piston type full use could be made of the experiences gained in the development of the reciprocating steam engine and up to the present date piston type pumps are extensively used, especially for low vacua and large volumes to be evacuated.

But for high vacua the effects of vapours, leaks and dead space cannot be neglected. Vapours can be condensed in cold traps and this is done effectively with many kinds of high vacuum pumps. Leaks must be rendered harmless by suitable design and special packings where the piston passes through the cylinder cover. The dead space which causes the same volume of air to be alternately expanded and compressed with each piston stroke was found to be most harmful. Here at last a solution was found by Fleuss[43] which solution at the same time also overcame the difficulty with leaks through the piston rod packing. In Fleuss's design the suction valve is not arranged as was done before in the bottom of the cylinder but a suction inlet is arranged at a distance from the bottom so that the piston passes at the down stroke below the inlet. A quantity of a liquid, preferably oil, always covers the piston. A valve arranged in the piston prevents a vacuum being formed below the piston at the commencement of the upstroke. The piston at the end of the upstroke opens the delivery valve arranged at the top of the cylinder and this valve is also covered with oil. Baffle plates arranged above this valve prevent splashing of the oil when the pump is at work (Fig. 7). The Fleuss pump, better known under the name "Geryk pump," is still used to-day for schools and laboratory experimental work, especially where hand drive is desirable, the single-stage design being suitable for an ultimate vacuum of .02 mm. Hg and the double-stage design for 10^{-5} mm. Hg with a piston displacement with different sizes of about 300-6,000 and 1,500-7,000 cu. in. per min. respectively. But it is also applied to some extent on actual production circuits when it is usually motor-driven, although generally it has been now replaced by rotary pumps. It should be stated that "Geryk pumps" is a trade name introduced by the Pulsometer Engineering Co. who were the first to manufacture the Fleuss design, and the name is now used for the whole range of their air pumps, reciprocating as well as rotary types.

An important condition for Fleuss's pump is complete purity of the oil applied. Even small contents of humidity which combine with the oil to an oil-water-emulsion impair the working of the pump. The water droplets evaporate when the piston is moved downwards into the vacuum above the piston and therefore a vacuum of only about 15 mm., i.e., the vapour pressure of water at room temperature, is obtainable. The use of phosphorus pentoxide traps or the like is indispensable.

The Fleuss pump was also built in Germany by Arthur Pfeiffer, Wetzlar, and in two modified designs with telescopic piston or with back flow valve by Max. Kohl, Chemnitz.[44]

An improved type was proposed by Gaede[45] and used mainly for demonstration purposes in which three pistons are arranged one above the other in a common cylinder. Pistons and intermediate fixed walls contain valves. Special means are provided for separating the condensed water vapours from the oil and the pump is therefore little affected by water vapours.

Transition Period

Before dealing with the modern development two designs should be mentioned which in the last decade of the 19th century and the first of the 20th were quite extensively used. Although the designs have now been superseded they may still be found occasionally in laboratories and factories. They work on a principle characterised by Prof. Andrade with the words "gas meter run backwards." They consist of a drum, usually made of porcelain, fitted with two or three suitably-shaped channels. The drum rotates in a casing filled with mercury in such a manner that the gas is sucked from the recipient and passed into the upper part of the casing connected to a fore-vacuum pump. One design proposed by Barr & Stroud[46] is shown in Fig. 8. In another design the rotating drum with horizontal axle is replaced by a helical wheel with inclined axle and conical core.

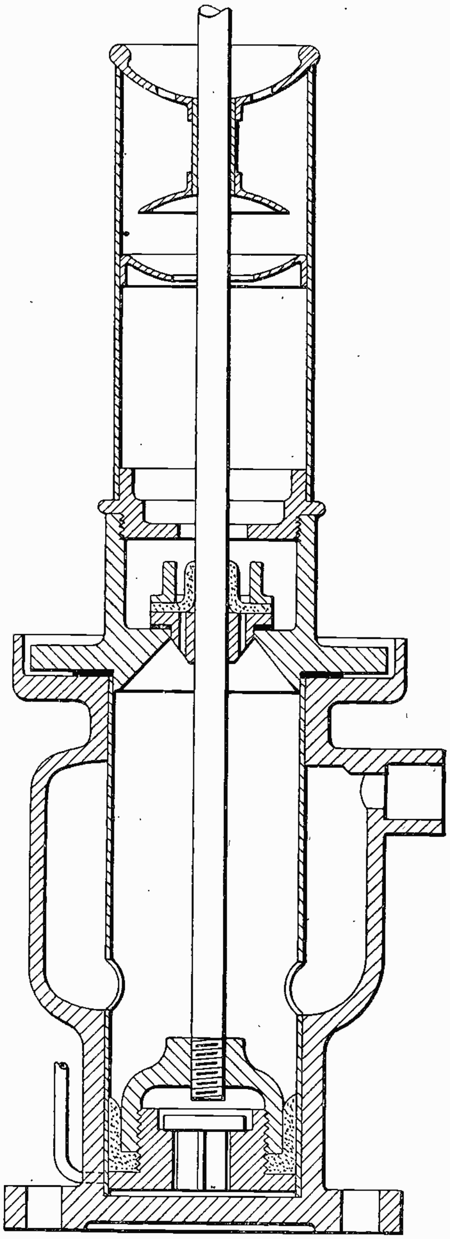


Fig. 7. Fleuss's pump ("Geryk" pump)

In Gaede's rotary mercury pump,[47] similar to Barr & Stroud's first design, the difficulty of keeping the packings air-tight is overcome by passing a finger-shaped tube connected to the recipient through the glass wall of the casing and letting it end within the upper part of a smaller porcelain drum connected by a porthole to the main drum (Fig. 9). The vacuum attainable with this pump is 10^{-5} mm. Hg but it needs a rather large mass of mercury and is not suitable for condensible vapours. Its speed is about 100 cm.^{3}/sec. but this decreases rapidly at about 10^{-3} mm. Hg and will be only 25 cm.^{3}/sec. at 10^{-5} mm. Hg.

If the rotary mercury pump stops for any reason a special design may be applied which allows of connecting the recipient directly with the fore-pump but in general the pump may be stopped without deterioration of the vacuum already attained. It is usual to admit atmospheric pressure only slowly on the high-pressure side if for any reason the fore-pump stops working. Otherwise there is the danger that the porcelain drum is damaged by the air rushing in. The same danger exists if a larger leak develops on

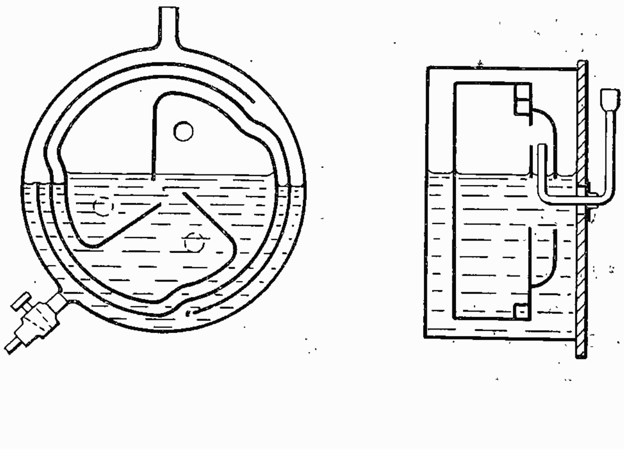


Fig. 9. Gaede's rotary mercury pump

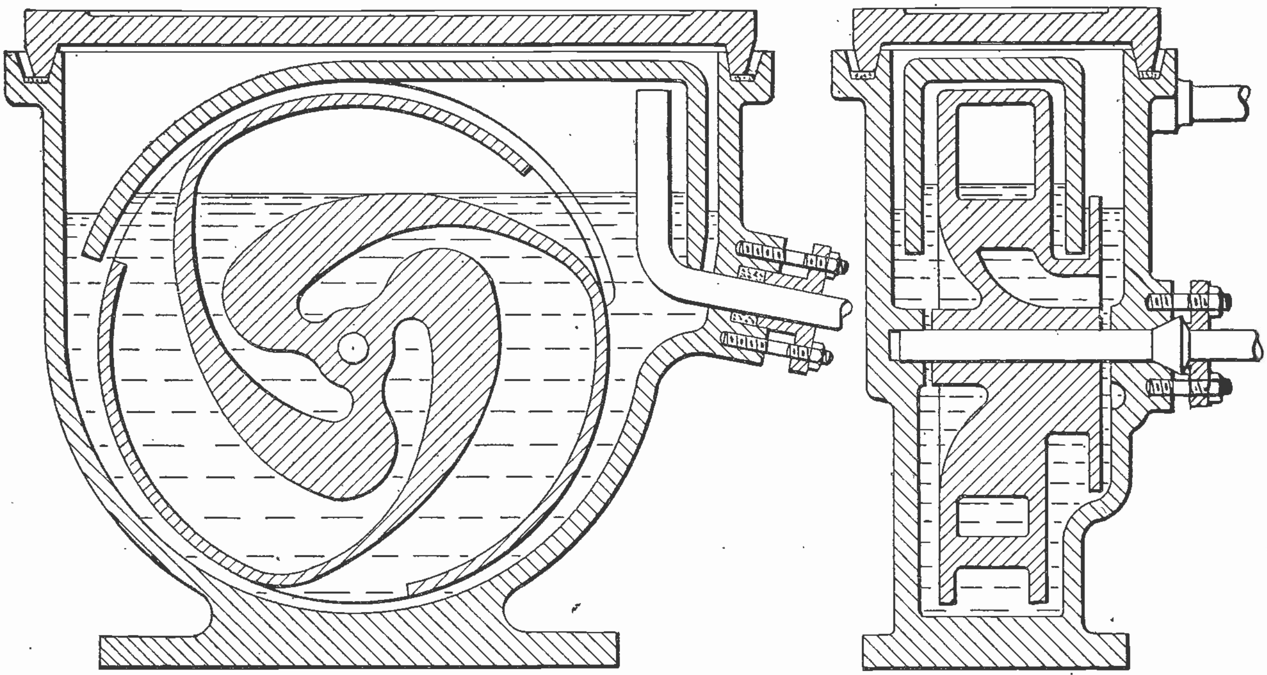


Fig. 8. Barr and Stroud's pump

the low-pressure side, *e.g.*, if in evacuating lamp bulbs one of them breaks. For this reason, porcelain drums were replaced by steel drums (A. Pfeiffer, Wetzlar), or the more sturdy helical design mentioned above was applied (Hoffmann). In this latter design the helix consisted of a single turn made of porcelain of such a width that a hand could be passed through it and the thickness of the porcelain prevented the danger of breakage.

(To be continued)

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Apparatus for the Investigation of Inter-Lens Shutters

By K. ONWOOD*

This paper describes three types of apparatus which have been developed and successfully used for investigation of the operation characteristics of interlens shutters. The first is no longer used for its original purpose but is included for completeness and the fact that it has several other uses.

1. Integrating Photometer.

THIS apparatus was made quickly when no other methods were available and is run from a 12-volt battery. The circuit (Fig. 1) consists of a standard electrometer valve measuring the charge introduced on a capacitor from a vacuum photo-cell. The amount of charge is determined by a calibrated potentiometer, the accuracy of measurement therefore being independent of valve characteristics.

This potentiometer, together with the various valve potentials, is standardised with the switch S2 in position 1. This connects the meter across a portion of the potential divided, and the resistance R_1 is varied until a definite deflection is obtained. When S2 is returned to position 2, it places the meter in the anode circuit of the electrometer valve and is also coupled to a circuit to provide a backing-off current. A separate light source is provided at a distance of about 10 in. from the shutter, and therefore the intensity of illumination over the area of the shutter opening is constant. When the shutter is opened, the light passes through on to a diffusing screen and is then projected on to the photo-cell. The screen is necessary to prevent ingress of moisture and to preserve the insulation.

In use, the shutter is opened on "time exposure" and the light intensity is adjusted until the meter gives a deflection which is precisely cancelled by setting the main potentiometer R_3 to five divisions. Since ten divisions on this potentiometer are equivalent to one volt, this means that ½ volt has been developed across the 2 megohm resistance in series with the photo-cell. This standardises the charging current to a definite value.

The correct capacitor is selected by S4 and the switch S3 is pressed, which open-circuits the 2 megohm resistor, and the shutter is operated. The meter is then reset to zero by means of the potentiometer R_3, its reading then indicating directly the total effective exposure.

Now the instrument is standardised by developing a voltage of 0.5 across 2 megohms. The generated current is 0.25 μA and, provided the charging current is the same, we have for unity voltage across the capacitor which is given on a correct exposure

$$Q = it = CV$$

The total charge $= \int_0^{T} .25.10^{-6}\, dit = 1.C/10^6$

and therefore $T/4 = C$.

Therefore for an exposure of 1/25th of the second we need a capacity of .01 μF and 1/100th sec. of .0025 μF, etc. If it is wished to measure the total open-close time, the iris diaphragm can be closed down to a small aperture, the light intensity increased and the test repeated. The shutter efficiency is then given by

$$\frac{\text{Total effective exposure}}{\text{Total open-close time}} \times 100\%$$

Care has to be taken over the accuracy and insulation of the components and in particular a Baird V.A.26 was found to be one of the only photo-cells with a low enough dark current to give good results.

The overall accuracy depends on the standardisation of the main potentiometer R_3, the two megohm resistor, the selector capacitor, the linearity of the cell and the linearity of the charging current. The first of these can all be maintained at a good accuracy. As regards the charging current, the cell is energised by a P.D. of 10 volts. Therefore, at the end of the test, the charging current is reduced to 9/10ths of its original value, due to the 1-volt charge across the capacitor. This change, if assumed to be linear with time, which is nearly the case at the commencement of an exponential curve, could be compensated for if the calibrating current was 9.5/10ths of the commencing charging current. (This is obtained since 0.5 volts are developed across the resistor leaving only 9.5 volts across the cell, during the calibration). Therefore, when unity voltage is developed across the capacitor, the average charging current is approximately correct. If greater accuracy is required a higher voltage source could be used across the cell.

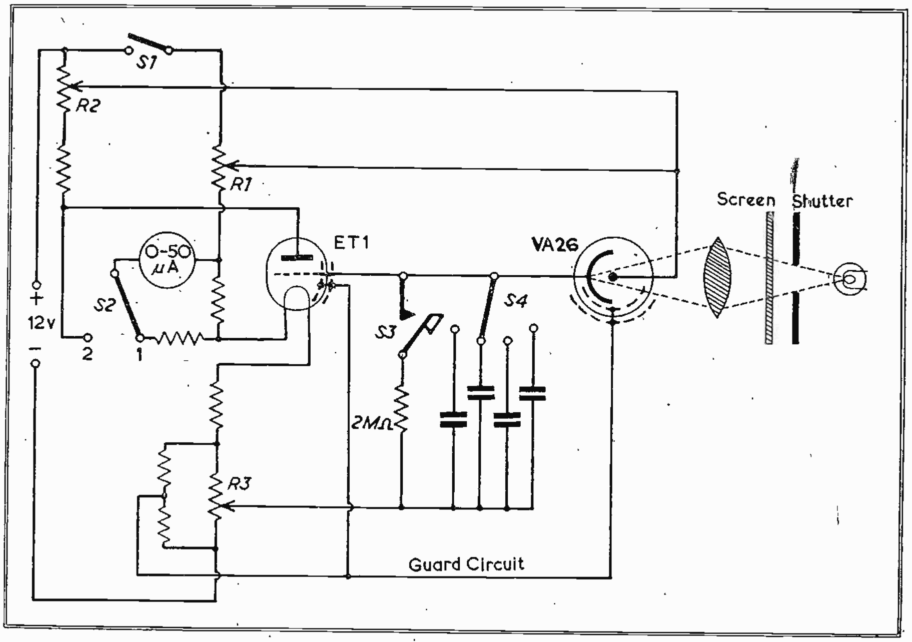


Fig. 1. Circuit diagram of integrating photometer

Shutter Operation Curve Tracer.

This apparatus was constructed to produce a trace on a cathode-ray

* Gambrell Bros., Ltd.

tube in which the ordinates were proportional to shutter opening and the abscissa to time. Therefore, all the information as to the speed, efficiency and operation of the shutter blades is presented and if required can be photographed for later study.

The equipment consists of a light source which cause a beam of light to pass through the shutter when open and impinge on a photo-cell, which is connected through a D.C. amplifier to one Y-plate of a double beam cathode-ray tube. The other Y-plate is taken to a timing device consisting of a 250 c/s. tuning fork, or 50 c/s., according to the speed limit being measured. The X-plates are taken to a single stroke time base, the frequency of which can be adjusted to suit the timing conditions of the shutter under test. A shift control for the trace is also provided.

It is necessary to ensure that even illumination is exposed over the whole area of the shutter, so that the light transmitted is always proportional to the area open. This was done optically and a converging beam was passed from the shutter to the photo-cell. As it was required to operate the instrument entirely from the mains the lamp was energised from rectified and smoothed A.C. A spring loaded release gear was fitted to ensure that the time base could be triggered consistently, with the correct amount of lead to bring the trace central on the tube. On pressing the release lever, the striker lever travels downwards, open-circuiting the time base capacitor which commences a charging stroke. After a suitable delay, the striker hits the shutter operating lever, giving the required exposure. Final centring of the trace is made by the shift control, the time base sweep being several times greater than the tube width to allow a wide range of adjustment. Owing to this limitation, speeds below 1/10th second could not be tested visually, but checks could be made at lower speeds by disconnecting the time base and driving the film in the camera at constant rate to provide the time axis. The instrument is now being modified to include an automatic delay device so that speeds down to one second may be investigated visually.

A Cossor double-beam G tube was used and it was found that the afterglow was sufficient for reasonable measurements to be made on the trace provided the tube was well shielded from external light. Photo-

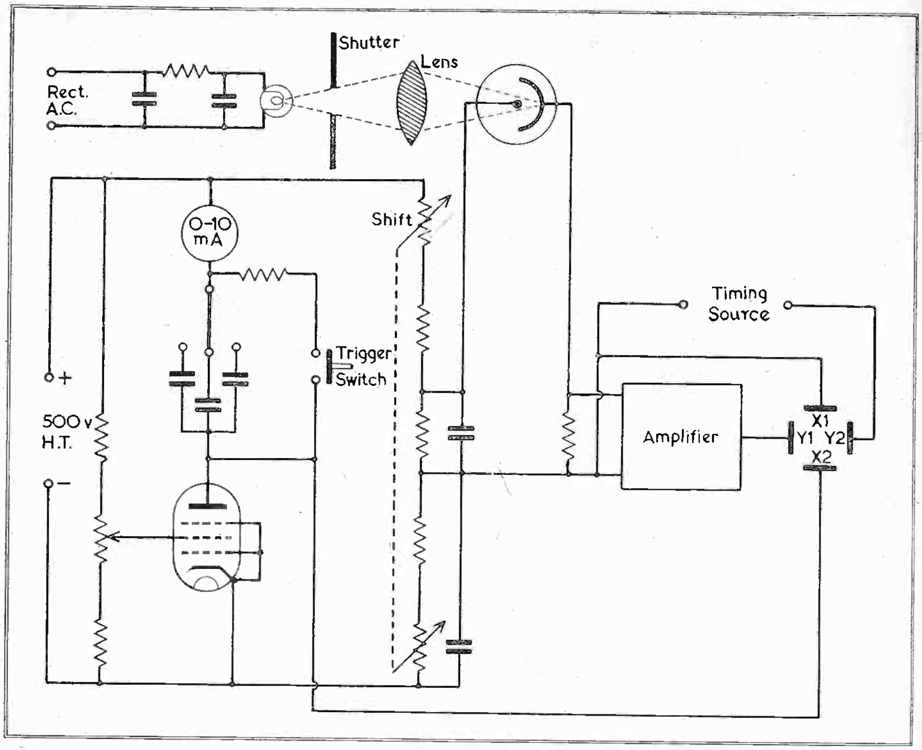


Fig. 3. Basic circuit of operation curve tracer

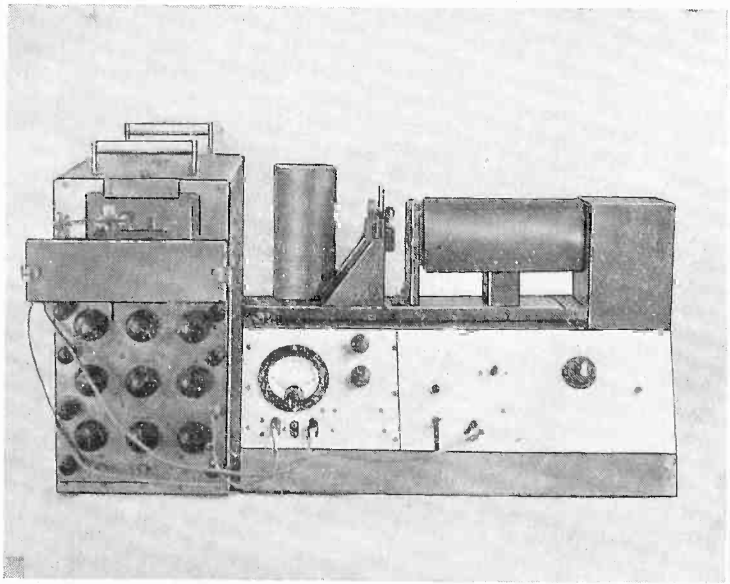


Fig. 2. Shutter operation curve tracer

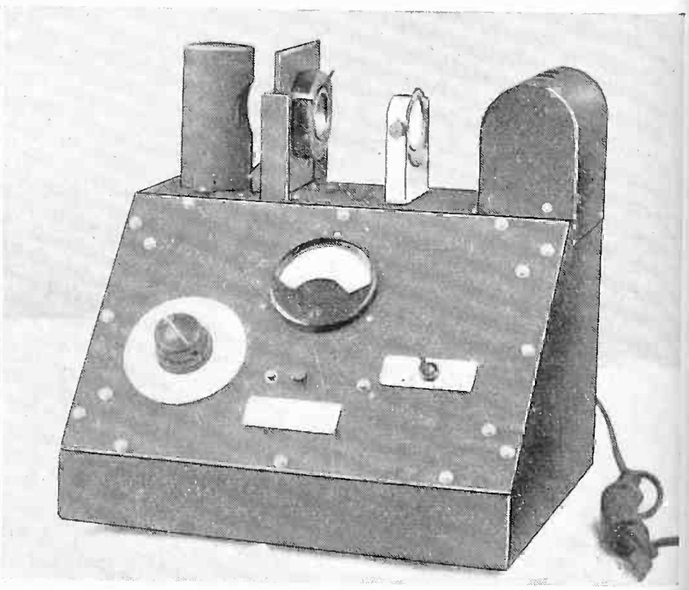


Fig. 5. Shutter comparator

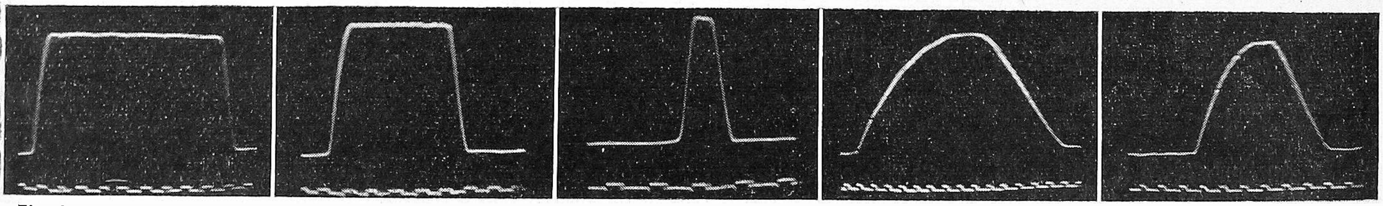


Fig. 4. Exposures of 2-bladed and 3-bladed shutters. Left to right : *Compur rapid shutter :* **Exposures nominally 1/25, 1/50, 1/200 showing good timing speeds and efficiencies.** *Pronto 2-bladed Shutter :* **Exposures nominally 1/25 and 1/50, showing timing errors and lower efficiencies. Timing marks all 4 milliseconds**

graphs were taken with a Cossor camera and Ilford BX5GY film developed in ID5 solution. Typical exposures of a two-bladed and three-bladed shutter are given in Fig. 4 which demonstrates the importance of efficiencies. The efficiency of a shutter is obviously obtained by taking the ratio of the curve area to that of the rectangle containing the curve. Measurements were made on magnified projections of the photographs.

The circuit and general arrangement of the instrument are shown in Figs. 2 and 3. It was made to adapt to a standard double-beam oscilloscope so as to retain the versatility of the latter instrument. The camera is shown in position. The meter was used for setting the time base speeds to correspond with the related shutter speeds.

The instrument as described above has been in use for about two years and was exhibited at the Physical Exhibition in January, 1946. An instrument working on the same principles, and embodying several refinements has been recently described by Messrs. Dighton & Ross.*

Shutter Comparator.

This third instrument was developed for the production testing of shutters and is originally calibrated by means of a " standard shutter " obtained from tests on the cathode-ray tube gear. The first has been in use for over a year and has proved quite satisfactory, although recent modifications have given far greater stability and speed in use.

The circuit and general outline are given in Figs. 5 and 6 and a brief description of the circuit is given under. A lens is used to concentrate the light from the lamp to a focus on the shutter blades at the point of opening; this beam then diverges and covers the whole sensitive area of the photo-cell. Therefore, we have maximum light transfer and therefore maximum voltage developed across the cell for a very small opening of the shutter blades. This voltage, which is negative going, is connected to the grid of the amplifier valve V1, which in operation is driven towards cut-off. It will be seen that this arrangement generates an almost square-wave voltage at the anode of the valve, the duration of which is equal to the total open time of the blades. The anode of this valve is directly connected to the grid of V2 through

(*Continued on p. 16*)

* *Photo: Journal*, p. 86B, 1946

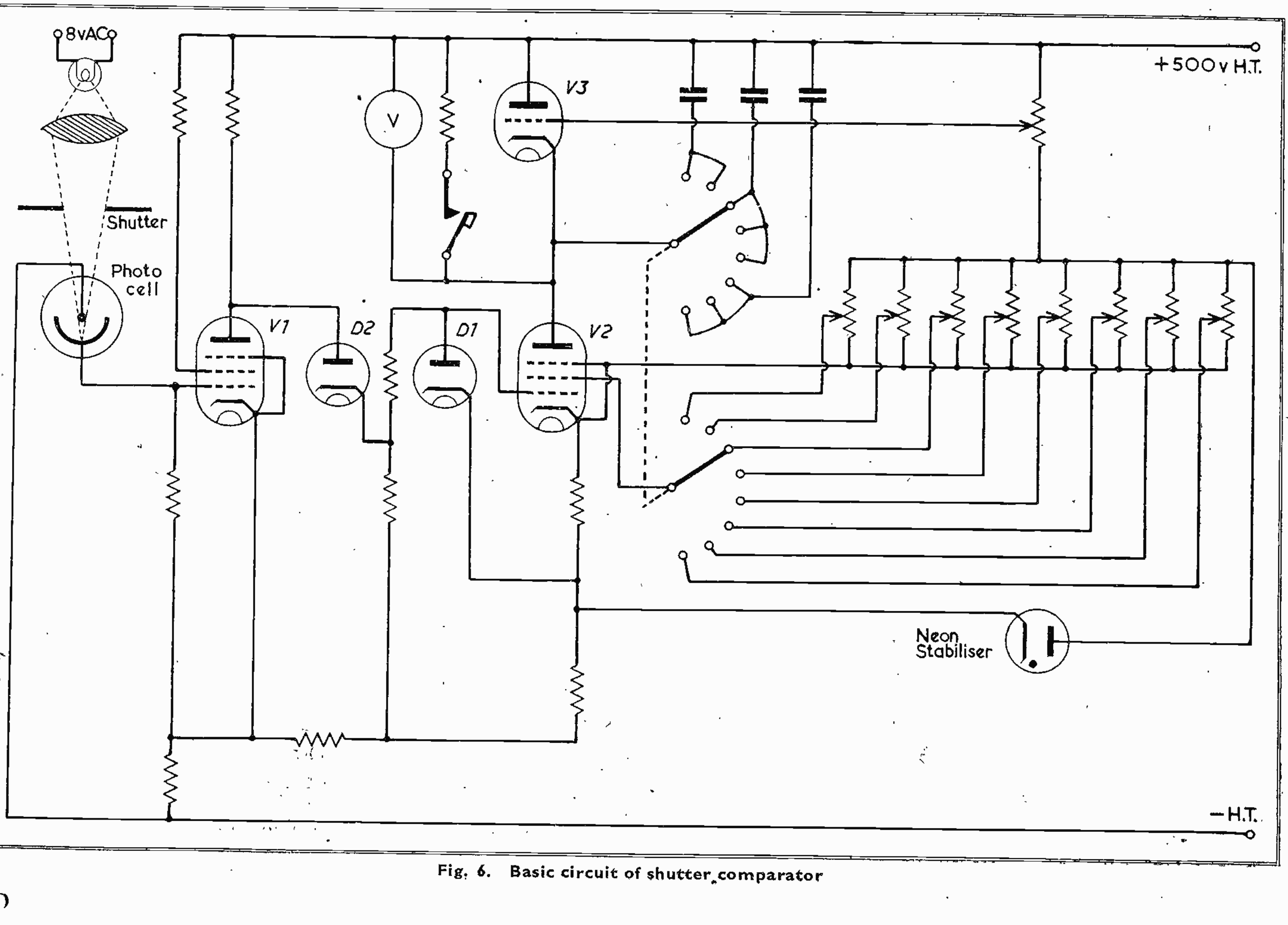


Fig. 6. Basic circuit of shutter comparator

The Cathode-Follower — *Linear Theory* *Part I of a Series* †

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

Author's Note : Many articles on the cathode follower with non-reactive load have already appeared in the literature, but almost all of them have been concerned with some limited aspect or aspects of the subject. The present series is the result of an attempt by the author to develop the subject in a more logical and comprehensive way. A number of new and important cheorems and constructions were discovered in the process, and these are published for the first time. It is the author's hope that the series will prove to be a 'definitive' statement of the basic theory of the circuit.

A number of detailed theoretical points not essential to the development of the main argument have been printed in smaller type and enclosed in angles. These can be omitted at first reading.

1. The Basic Anode Current Equation of a Triode

1.1 General

THE conventional anode current characteristics of a typical triode are shown in Figs. 1 and 2. Fig. 1 shows them as "Mutual Characteristics" with V_g as independent variable and V_a as parameter; Fig. 2 shows them as "Anode Characteristics" with V_a as independent variable and V_g as parameter. The (approximate) general equation to these characteristics is usually written in the form

$$I = \frac{V_a + \mu V_g}{R_a} \quad \text{.................... (1.1)}$$

This equation is approximate, firstly because it neglects the curved tails (dotted in Figs. 1 and 2) on the characteristics, and secondly because it assumes that the anode characteristic $V_g = 0$ in Fig. 2 would, if extended as a straight line, pass exactly through the origin of the co-ordinates, which is not usually the case. But the inaccuracies that Equation (1.1) introduces into the theory are very slight and Sections 1 to 9 will be based on it entirely. The characteristics (the *full* lines in Figs. 1 and 2) corresponding to this equation, and any others derived from them, will be called "*idealised*" characteristics.

The first step in the theory is the substitution of μ / g_m for R_a in equation (1.1) which then becomes

$$I = g_m(V_g + V_a/\mu) \quad \text{........... (1.2)}$$

This form is preferred since it shows more clearly than does (1.1) that the "slope" $\partial I/\partial V_g$ of the mutual characteristics is g_m. Moreover, the quantity $1/g_m$, which is of fundamental importance in cathode - follower theory, now appears in the results explicitly, and not in the disguise R_a/μ. For the sake of completeness, however, the alternative "R_a" forms of the principal results are given later (Appendix I).

1.2 The "Mutual Resistance"

The quantity $1/g_m$ will be written as R_m and called the "*Mutual Resistance*" of the valve. It is of practical as well as theoretical importance, since it is of a convenient magnitude numerically—usually between a hundred and a thousand ohms. The relationship

$$\mu = R_a / R_m \quad \text{...................... (1.3)}$$

is often useful and should be noted.

SYMBOLS USED

I	**The Valve Current.** Also referred to as the "cathode current" and sometimes as the "output current." (Except in Appendix V, it is the "anode current" too.)
V_a	**The Anode Voltage.** The D.C voltage of the anode relative to the cathode at any time, irrespective of the external circuit conditions, e.g., whether there is any cathode (or anode) load present or not.
V_g	**The Grid Voltage.** The D.C. voltage of the grid relative to the cathode at any time, irrespective of the external circuit conditions. It is, in general, a negative quantity.
μ	**The Amplification Factor of the Valve.** Mathematically, it is $\delta V_a/\delta V_g$ (I constant).
R_a	**The Anode Resistance of the Valve.** Sometimes known as the "dynamic resistance" or "anode slope resistance." Mathematically, it is $\delta V_a/\delta I$ (V_g constant)
gm	**The Mutual Conductance of the Valve.** Mathematically, it is $\delta I/\delta V_g$ (V_a constant).
R_m	**The Mutual Resistance of the Valve.** The reciprocal of gm. Mathematically, it is $\delta V_g/\delta I$ (V_g constant).
R_c	**The External Cathode Resistance.**
V_i	**The Input Voltage.** The D.C. voltage of the grid relative to H.T. negative at any time. May be either negative or positive and is equal to V_g when R_c is zero.
V_o	**The Output or Cathode Voltage.** The D.C. voltage of the cathode relative to H.T. negative at any time. Is always positive or zero.
V_{ht}	**The H.T. Voltage.**
D	**The Degeneration Factor.** The ratio of the "effective mutual conductance" to the mutual conductance in the absence of degeneration.
Δ	**"Change in."** Not necessarily "small change in." Is also used to denote A.C. quantities in general.
N	**The Ratio of R_c to R_m.**
V_m	**The Maximum D.C. Output Voltage** available for a given value of R_c without driving the valve into grid current (assuming grid current to start at $V_g=0$). More precisely, the common D.C. voltage of the grid and cathode (relative to H.T. negative) when $V_g=0$.
I_m	**The Maximum D.C. Output Current** available for a given value of R_c under the same conditions. More precisely, the D.C. output current when $V_g=0$.
V_{GB}	**The "Idealised" Grid Base** corresponding to an H.T. voltage V_{ht}. Is equal to V_{ht}/μ.
I_1	**The Value of I at $V_g=0$** on the mutual characteristic $V_a=V_{ht}$. Is equal to V_{ht}/R_a or $g_m V_{GB}$.

2. The Triode with Cathode Degeneration

2.1 Nomenclature

When an un-bypassed cathode resistance R_c is introduced (*see* Fig. 3) it becomes necessary to distinguish between the voltages of the grid and anode relative to H.T. negative and their voltages relative to cathode. The former will be written as V_i (the "input voltage") and V_{ht} (the "H.T. voltage") respectively; while the latter remain as V_g (the "grid voltage") and V_a (the "anode voltage") respectively. The voltage of the cathode will be written as V_o (the "output voltage") but may also be referred to as the "cathode voltage." These conventions are illustrated in Fig. 3.

The most obvious consequence of the introduction of the cathode resistance is that the effect of the input voltage is lessened, since only that part of it which appears between grid and cathode, *viz.*, V_g, is able to affect directly the current through the valve. The resistance R_c is said to introduce *degeneration*, and the resistance itself is called a *degenerative* resistance.

If the relationship between the current I and the two new variables V_i and V_{ht}, is plotted in the same way as was the relationship between

* Royal Naval Scientific Service

† MS. first submitted Dec. 1945 and in final form Dec. 1946.

I and V_g and V_a in Figs. 1 and 2, similar curves are obtained. These will be called the *degenerate characteristics* of the triode for that particular R_c. The equation to them will be found in paragraph 2.2 below. It should be noted that all the quantities involved continue to be D.C. quantities as in Section 1. Confusion will result if this is forgotten. For example, it is clear that V_o must be greater than V_i since the grid would otherwise be positive with respect to the cathode, but the inequality is reversed, *i.e.*, $\Delta V_o < \Delta V_i$, when incremental ("signal" or A.C.) voltages are considered as in paragraph 4.4.

2.2 The Equation to the Degenerate Characteristics

Equation (1.2) now becomes

$$I = g_m\left(V_i - V_o + \frac{V_{ht} - V_o}{\mu}\right)$$

or, re-arranging,

$$I = g_m\left(V_i + V_{ht}/\mu - \frac{\mu+1}{\mu} V_o\right) \quad \ldots\ldots\ldots\ldots (2.1)$$

But, from Fig. 3, $V_o = IR_c$. Substituting this in (2.1) and solving for I,

$$I = D.g_m(V_i + V_{ht}/\mu) \quad \ldots\ldots (2.2)$$

$$\text{where } D = \frac{R_m}{R_m + \frac{\mu+1}{\mu} R_c} \quad \ldots\ldots\ldots\ldots (2.3)$$

This is the fundamental current equation of the triode with cathode degeneration. The factor D will be called the *Degeneration Factor*. It is clearly less than unity.

2.2.1. *The "Effective g_m."* Comparison between equations (1.2) and (2.2) shows that the multiplier of the voltage $V_g + V_a/\mu$ in the former is g_m, whereas the multiplier of the voltage $V_i + V_{ht}/\mu$ in the latter is D.g_m. That is to say, *the "effective mutual conductance" when cathode degeneration is present is D times the original mutual conductance.* This result finds practical application in the use of a variable cathode resistance as a Gain Control. Equation (2.3) shows that such a gain control is not linear since D does not vary linearly with R_c.

2.2.2. *The "Effective R_a."* Equation (2.2) can be re-written as $I = (V_{ht} + \mu V_i)/(R_a/D)$ which shows (c.f. Equation (1.1)) that *the "effective anode resistance" when cathode degeneration is present is $1/D$ times the original anode resistance.* Written in full, it is, from equation (2.3), $R_a + (\mu+1)R_c$. The "effective anode resistance" can clearly be made many times greater than R_a by use of the appropriate value of cathode resistance.

2.2.3. *The "Effective μ."* Inspection of equation (2.2) shows that the co-

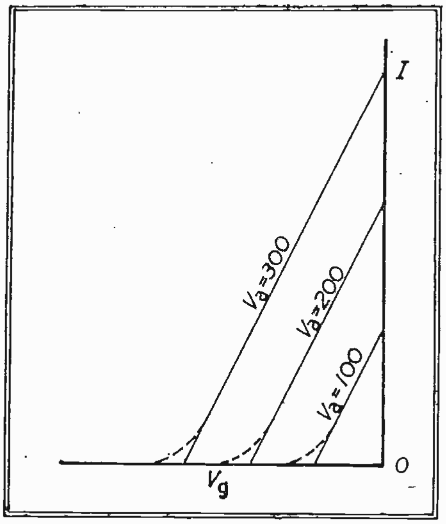


Fig. 1. Conventional mutual characteristics of ordinary triode

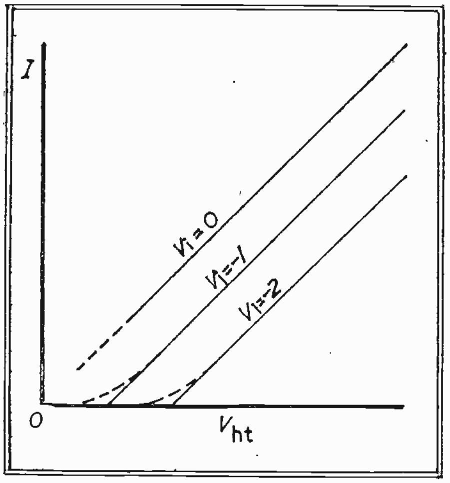


Fig. 2. Anode current-grid voltage characteristics of ordinary triode

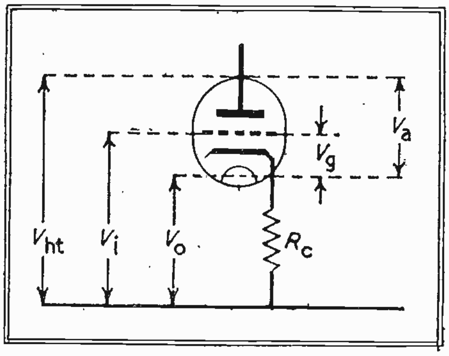


Fig. 3. Triode with cathode resistance, showing the parameters discussed in the text

efficients of the voltages V_i and V_{ht}, respectively, in the expression for the current I, are in the ratio μ:1, *i.e.*, a change of 1 volt in the input voltage has μ times the effect on the valve current that a change of 1 volt in the H.T. voltage has. This is, of course, also the case for changes in V_g and V_a, respectively, when the triode is used normally. Hence *the "effective amplification factor" when cathode degeneration is present is the same as the original amplification factor μ.*

2.2.4. A practical interpretation of the "effective g_m," the "effective R_a" and the "effective μ" should be noted. They are the parameters the valve would appear to have if it and its cathode resistance were in a sealed box with the grid and anode leads brought out and labelled correctly, but with a lead from the "earthy" end of R_c brought out and falsely labelled "cathode." Similarly, if the mutual and anode characteristics of such a "valve" were measured experimentally, the results would be the degenerate characteristics whose equation has been found above.

2.3 The Form of the Degenerate Characteristics

Figs. 4 and 5 show the revised forms of the two families of characteristics when degeneration is present, for a particular value of R_c. Fig. 4 shows the degenerate mutual characteristics with V_i as independent variable and V_{ht} as parameter. They are reduced in slope by the factor D, but each intersects the voltage axis as before at $-V_{ht}/\mu$. (These curves should be compared with the ordinary "dynamic" characteristics of a triode whose *anode* load is R_L. It will be found that their slopes correspond exactly if $R_L = (\mu+1) R_c$). Fig. 5 shows the degenerate anode characteristics with V_{ht} as independent variable and V_i as parameter. They are reduced in slope by the factor D, but each intersects the voltage axis as before at $-\mu V_i$.

2.4 Some Approximate Results when $\mu >> 1$

If $\mu >> 1$, as is almost always the case, the coefficient $(\mu + 1)/\mu$ of the term R_c in the denominator of equation (2.3) can be taken as unity and the following approximate expression for the Degeneration Factor is obtained:

$$D \approx \frac{R_m}{R_m + R_c} \quad \ldots\ldots\ldots\ldots (2.4)$$

This is a useful result since, as was pointed out above, the "R_m" of a valve is always of a convenient magnitude numerically, and if R_c is thought of in terms of R_m, the value of D can be calculated quickly; *e.g.*, if R_c equals R_m, D is one-half, if R_c is twice R_m, D is one-third, and so on.

Since in practice μ is always much greater than unity, it might seem unnecessary to consider any equations other than the approximate ones, but this is not so. When, later, the voltage between the grid and cathode is being considered, for example, the accurate forms are required, since to take the small difference between two relatively large quantities, one of which was only approximate, might give a totally incorrect result.

2.4.1. The "Effective Mutual Conductance" (para. 2.2.1 above) now becomes $1/(R_m + R_c)$ and the "Effective Mutual Resistance" $(R_m + R_c)$, results which are sometimes useful.

2.4.2. It was shown above that the expression (2.3) for the degeneration factor D could be simplified to the form (2.4) under the condition $\mu >> 1$. The simplification consisted in the neglecting of the term R_c/μ in the denominator $R_m + R_c + R_c/\mu$. This approximation is valid if R_c/μ is small compared with *either* of the other two terms, *i.e.*, compared with either R_m or R_c. It was the second of these alternatives that was assumed above when the approximation was made. The other alternative, *viz*: $R_c/\mu << R_m$ can be rewritten as $R_c << R_a$ from equation (1.3), and it will be clear from the results to be obtained in Section 7 that under this condition the rise in cathode voltage and hence the fall in anode voltage must be small. On the other hand $\mu >> 1$ is the condition that the change in anode voltage (though not necessarily small) shall have negligible effect on the valve current. The two conditions taken together therefore ensure simply that changes in the anode voltage shall be without appreciable effect, either through being small ($R_c << R_a$, μ unspecified) or because of the intrinsic design of the valve ($\mu >> 1$, R_c unspecified).

2.5 The Case $R_c >> R_m$

If the degeneration is great, *i.e.*, if $R_c >> R_m$, the expression for the Degeneration Factor can be simplified still further to $D \approx R_m/R_c$. The "Effective Mutual Conductance" then becomes $1/R_c$, approximately, and the current equation (2.2) becomes $I \approx (V_i + V_{ht}/\mu)/R_c$.

3. The Fundamental Current Equations of the Cathode-Follower

3.1 The D.C. Current Equations

Equation (2.2) of the last section was the equation for the anode current of a triode with a resistance R_c in its cathode, a voltage V_i on its grid and a voltage V_{ht} on its anode, both voltages being relative to H.T. negative. If now the voltage V_{ht} is supposed fixed and V_i taken as the only independent variable, the same equation clearly expresses the current in a cathode-follower (cathode resistance R_c and H.T. voltage V_{ht}) in terms of its input voltage V_i. Equation (2.2) is therefore the *Fundamental Current Equation of the Cathode-Follower*. It is repeated here in its various forms for reference:

$$I = D \times g_m(V_i + V_{ht}/\mu) \quad \ldots \quad (3.1)$$

$$I = \frac{R_m}{R_m + \frac{\mu+1}{\mu}R_c} \times g_m(V_i + V_{ht}/\mu) \quad \ldots\ldots\ldots\ldots\ldots \quad (3.2)$$

$$I \approx \frac{R_m}{R_m + R_c} + g_m(V_i + V_{ht}/\mu) \quad (3.3)$$

3.2 The Current Characteristics

The above equations are equations to a straight line on the V_i, I graph which passes through the point $-V_{ht}/\mu$ on the voltage axis for all values of R_c, but whose slope depends on the value of R_c. Such a straight line will be called a "*Fundamental Current Characteristic*" *of the Cathode-Follower*. As defined by the above equations, it is, of course, an 'idealised" characteristic. Fig. 6 shows several such characteristics (the full lines) drawn for a given value of V_{ht}, but for various values of R_c. The departure of the true characteristics from the idealised ones is indicated in the same figure by the dotted tails added to the full lines.

The algebraic "slope" $\partial I/\partial V_i$ of the general current characteristic is, from equation (3.1), equal to $D.g_m$. When $R_c = 0$, $D = 1$ and the cathode-follower current characteristic becomes the ordinary "mutual" characteristic with slope equal to g_m. When R_c is very large, the slope becomes very small, and the characteristic lies very close to the voltage axis.

(It will be noted that nothing has been said concerning the *extent* of the characteristics. This will be considered fully in Section 6.)

3.3 The A.C. Current Equations

The equations (3.1) - (3.3) given above were the full D.C. current equations of the cathode-follower. If V_i and I are replaced by $V_i + \Delta V_i$ and $I + \Delta I$, respectively, in equation (3.3) say, and equation (3.3) itself then substracted from the result, the following relationship between ΔV_i and ΔI is obtained

$$\Delta I \approx \frac{R_m}{R_m + R_c} \times g_m \Delta V_i$$

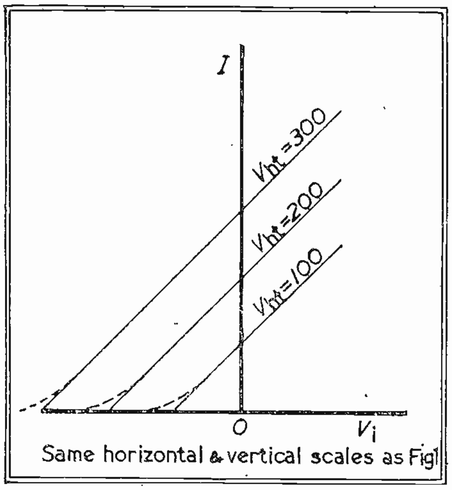


Fig. 4. Degenerate mutual characteristics of triode

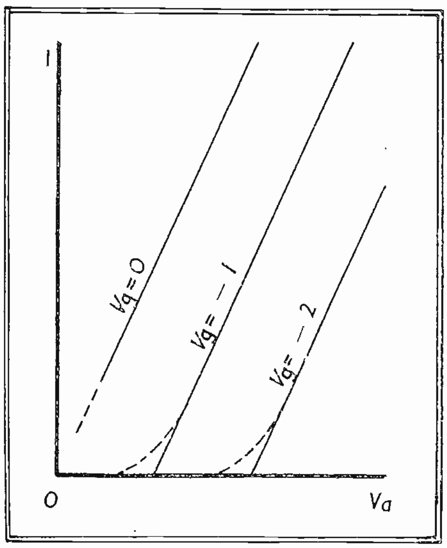


Fig. 5. Degenerate anode characteristics of triode

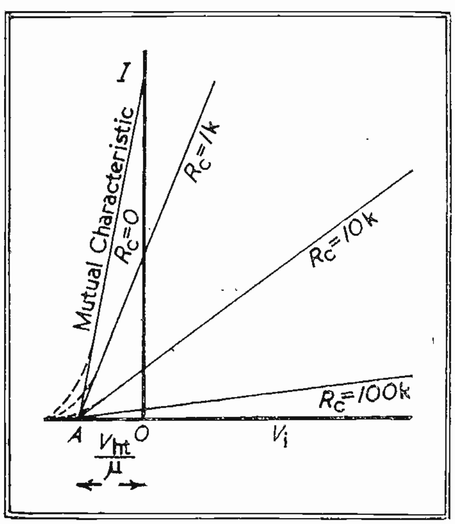


Fig. 6. Cathode-follower current characteristics for various values of Rc

or alternatively,

$$\Delta I \approx \frac{\Delta V_i}{R_m + R_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3.4)$$

This is the (approximate) *Incremental (or* A.C.) *Current Equation of the Cathode-Follower.* The corresponding exact relationship can be written down similarly from equation (3.2) if required. ΔV_i and ΔI are, of course, not necessarily *small* changes, but may be as large as the linearity of the characteristics will permit.

4. The Fundamental Voltage Equations of the Cathode-Follower

4.1 The D.C. Voltage Equations

Since $V_o = IR_c$, exact and approximate expressions for the output *voltage* of the cathode-follower are obtained at once from equations (3.2) and (3.3). They are, respectively:

$$V_o = \frac{R_c}{R_m + \frac{\mu+1}{\mu} R_c} (V_i + V_{ht}/\mu) \quad \ldots\ldots\ldots\ldots\ldots \quad (4.1)$$

$$\text{and } V_o \approx \frac{R_c}{R_m + R_c} (V_i + V_{ht}/\mu) \quad (4.2)$$

These are the *Fundamental Voltage Equations of the Cathode-Follower.*

4.2 The Voltage Characteristics

The above equations are equations to a straight line on the V_i, V_o graph which passes through the point $-V_{ht}/\mu$ on the input voltage axis for all values of R_c, but whose slope depends on the value of R_c. Such a line is a "*Fundamental Voltage Characteristic*" *of the Cathode-Follower.* As defined by the above equations, it is, of course, an "idealised" characteristic. Fig. 7 shows several examples drawn for a given value of V_{ht}, but for various values of R_c. The true characteristics depart from the idealised ones in the same way as did the current characteristics illustrated in Fig. 6.

4.3 The Gain of the Cathode-Follower

The algebraic "slope" $\partial V_o/\partial V_i$ of the voltage characteristics is the "Gain" of the cathode-follower for incremental or A.C. voltages. From equation (4.2), it is (approximately):

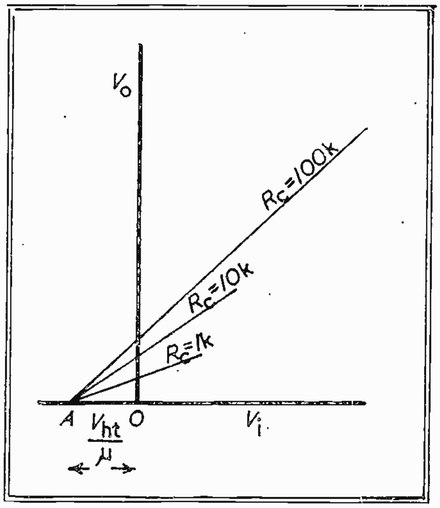


Fig. 7. Cathode-follower voltage characteristics for various values of Rc

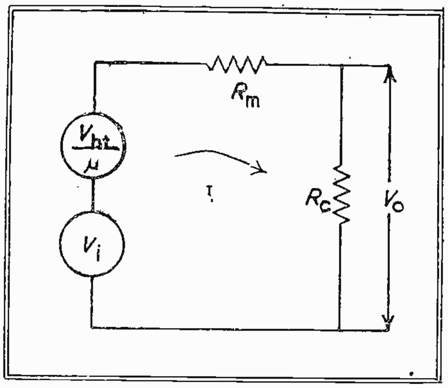


Fig. 8. Approximate equivalent D.C. circuit

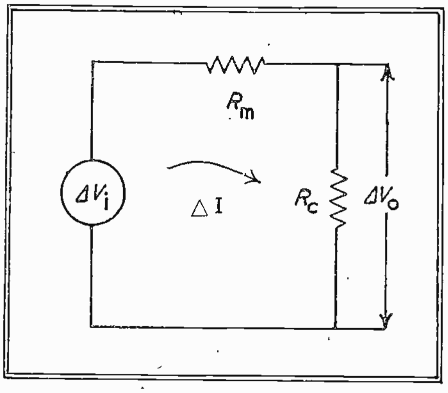


Fig. 9. Approximate equivalent A.C. circuit

$$\text{Gain} \approx \frac{R_c}{R_m + R_c} \quad \ldots\ldots \quad (4.3)$$

This can also be written: Gain $\approx N/(N+1)$, where $N = R_c/R_m$, which is sometimes useful. The gain approaches zero as R_c becomes very small and approaches *unity* (approximately) as R_c becomes very large.

4.3.1. More accurately from equation (4.1),

$$\text{Gain} = \frac{R_c}{R_m + \frac{\mu+1}{\mu} R_c} \quad \ldots\ldots\ldots \quad (4.4)$$

which approaches $\mu/(\mu+1)$ as R_c becomes very large.

4.4 The A.C. Voltage Equations

Equations (4.1) and (4.2) above were the full D.C. voltage equations of the cathode-follower. If V_i and V_o are replaced by $V_i + \Delta V_i$ and $V_o + \Delta V_o$, respectively, in equation (4.2), say, and equation (4.2) then subtracted from the result, the following relationship between ΔV_i and ΔV_o is obtained:

$$\Delta V_o \approx \frac{R_c}{R_m + R_c} \Delta V_i \quad \ldots\ldots \quad (4.5)$$

This is the (approximate) *Incremental (or* A.C.) *Voltage Equation of the Cathode-Follower.* The corresponding exact relationship can be written down from (4.1) if required. As in paragraph (3.3), ΔV_i and ΔV_o are not necessarily small changes, but may be as large as the linearity of the characteristics will permit. It will be seen that (4.3) and (4.5) are alternative ways of expressing the same result. Equation (4.5) could also have been obtained from equation (3.4) of course.

5. The Approximate Equivalent Circuits

5.1 Summary

The equations of the two preceding sections enable certain equivalent circuits to be established. Only the approximate ($\mu >> 1$) results will be given here, the exact results being considered in Appendix II.

5.2 The Equivalent D.C. Circuit

The relevant equations are (3.3) and (4.2) which can be re-written

$$I \approx \frac{1}{R_m + R_c} (V_i + V_{ht}/\mu)$$

$$\text{and } V_o \approx \frac{R_c}{R_m + R_c} (V_i + V_{ht}/\mu)$$

But these are the equations giving the current and the output voltage in the circuit of Fig. 8. The latter is therefore the *Approximate Equivalent* D.C. *Circuit of the Cathode Follower.* It should be noted that it is more complete than the A.C. equivalent circuits usually quoted in that it includes a "generator" for the H.T. voltage and gives the D.C. current through the load.

5.3 "Short-Cut" Proof

The same result can also be obtained directly from the fundamental equation (2.1), without mention either of the cathode load or of the characteristics. For, making the approximation $\mu + 1 \approx \mu$ and replacing g_m by $1/R_m$, equation (2.1) can be written $V_o \approx V_i + V_{ht}/\mu - IR_m$, which, by its form, establishes Fig. 8 immediately.

5.4 The Equivalent A.C. Circuits

If, in Fig. 8, V_{ht}, V_i, V_o and I are replaced by their differentials, ΔV_{ht} vanishes since V_{ht} is constant, and the circuit reduces to the circuit of Fig. 9, which is therefore the *Approximate Equivalent* A.C. *Circuit of the Cathode-Follower.*

5.5 "Short-Cut" Proof

The "direct" proof in this case can be written down from first principles. For, neglecting anode voltage changes, the basic A.C. equation of the triode is $\Delta I \approx g_m \Delta V_g$. This becomes, in the case of the cathode-follower, $\Delta I \approx g_m (\Delta V_i - \Delta V_o)$, which can be re-arranged as $\Delta V_o \approx \Delta V_i - R_m \Delta I$, and this equation, by its form, establishes Fig. 9 at once.

5.6 The Output Impedance

Fig. 9 illustrates the important fact that:—

> *The output impedance of the cathode-follower is approximately equal to R_m, the mutual resistance of the valve.*

(Compare the exact result given in Appendix II). The output impedance of the stage as a whole, including the cathode resistance R_c, is, by Thevenin's Theorem, $1/(1/R_m + 1/R_c)$.

To be continued.

Part 2 of this series will deal with the grid current points, maximum input and output, and prediction of the current characteristics. The Appendices referred to in the text will be given at the end of the series.

Investigation of Inter-lens Shutters—*continued from page 11*

—continued from page 11

the diode D2. Normally, V2 is cut off by the heavy negative bias applied to the grid.

As the voltage on the anode of V1 rises, it reaches a point where it is equal to the grid potential of V2 when D2 conducts and drives the grid of V2 to a steady potential determined by the point at which D1 conducts. This again is determined by the point to which D1 is connected on the potential divider. This "slices" the square-wave input and prevents any interference being transmitted to the grid of V2 as well as maintaining its potential at a constant value. The exciter lamp is a G.E.C. 8-volt sound projector lamp with a special filament producing a very low hum level. This, together with the limiting action of the diodes, allows the lamp to be run from A.C.

Now the square pulse on the anode of V1 is applied to the grid of V2 with constant amplitude and therefore the anode of V2 conducts for a time determined by the length of the pulse, the anode current being dependent only upon the screen volts. The screen voltage is selected by a switch from eight pre-set potentiometers located at the back of the instrument and fed from a regulated supply.

Ganged with this switch is another by which suitable capacitors are selected in the anode circuit to give a deflection on the voltmeter connected across them to register speeds of 1, ½, 1/5th, 1/10th, 1/25th, 1/50th, 1/100th and 1/200th of a second. This is a 0-300 volt electrostatic voltmeter and is calibrated in percentage error, 200 volts corresponding to zero error. Therefore 150 volts corresponds to 25 per cent. fast and 250 volts corresponds to 25 per cent. slow. The scale is very open over this range and 2 per cent. can easily be read.

Valve V3 is connected across the selected capacitor and is biased to conduct when the latter reaches 300 volts. This protects the meter from overloads due to the selection of a wrong range or in the event of the shutter sticking.

The instrument is calibrated on each range by a "standard shutter" by adjusting the relative screen potentiometer to show the same percentage error on the voltmeter as obtained by the cathode-ray tube tests. This is done on all the eight speeds in turn.

In use, the shutter to be tested, which is assembled on a rectangular plate, is slipped in the guides, the main switch set to the speed selected, and the push-button is pressed which open-circuits the selector capacitor and the shutter is operated. The percentage timing error is then read directly on the meter. The push-button is then released, which discharges the capacitor ready for the next test.

A safety flag automatically covers the photo-cell aperture when the shutter is removed and prevents direct light from reaching the cell.

It will be seen that this instrument is very quick in use and is sensibly independent of shutter efficiencies. Therefore, it can be used to compare the total open-close time of all types of shutters.

Its stability depends largely on the screen and filament volts of the charging valve V2 and the A.C. supply is therefore fed from a constant voltage transformer and the screen volts are also neon stabilised. After an initial warming-up period, the overall stability then becomes very good.

This instrument was exhibited at the last Physical Society's exhibition.

Prague World Fair, 1947

Over 2,000 stands containing nearly every kind of manufactured product were assembled at the Prague Fair, held in the autumn of 1947. The foreign section was confined to a small building and among the items shown were valves of Russian manufacture and cathode-ray tubes. No information on these was available on the stand. Philips displayed a wide range of valves, with electronic and X-ray equipment.

The radio receivers shown in the "home" section were comparable in price with the British counterparts, but the cabinets seemed more attractively designed. Although Czechoslovakia is far advanced in glass technique, there was no evidence of development of glass-metal seals.

Particulars of the receivers made by "Tesla" are printed in English for the benefit of visitors. The "Kongres" superhet is described as having a "physiological volume control," a most useful adjunct for irate listeners.

An Automatic Polar Diagram Recorder

With Application to the Testing of Radar Antennae

By A. H. BECK,* B.Sc. (Eng.), A.M.I.E.E., and S. A. TIBBS*

THE plotting of aerial polar diagrams is, at best, a laborious task, and if the beam angle is very small the work becomes very much harder. The present paper describes a method of automatic plotting, which is very simple in essence and application although it has not been described before.

Introduction

The standard method of plotting the polar diagram of decimetre and centimetre antennae has been described by Clayton, Houldin *et al.*[1] The aerial to be tested is erected at such a distance from a suitable transmitter that the received wavefront may be assumed to be plane. The signal is amplified in a linear amplifier and detector. The aerial is then rotated and the detector readings are plotted as a function of the angle between the axis of the aerial and the line directed to the transmitter.

Although this process seems simple enough it becomes very difficult to carry out if the beam is very narrow and the frequency very high. The reason for this is two-fold, one has to construct an accurate and backlash free gear train so as to be able to rotate the receiver through a small enough angle to allow sufficient readings to be obtained, which makes the speed of measurement so slow that there is an appreciable chance of the transmitted frequency changing during a measurement. Various ways out of this dilemma suggest themselves. One might use an ordinary electromagnetic Plan Position Indicator with the deflector coils connected to the receiver output instead of the time base. Such a system would draw a polar diagram which could be photographed and analysed at leisure. The speed of rotation of radar antennae usually lies between 1 and 60 r.p.m. so the frequency should not shift. However, it would be very difficult to obtain a good accuracy by this means for the following reasons. First, the angle subtended at the centre of the P.P.I. by the deflected spot would be of the same order as the angle of a narrow beam array and secondly the rotating mechanism would have to be considerably better than normal. Finally, photographic recording is always a nuisance even when elaborate apparatus is available, because of the time lost in processing.

Another method would be to use an "A" presentation with a time base proportional to the angle. The easiest way of doing this would probably be to cause the rotation of the aerial to rotate the arm of a linear potentiometer which is connected to a battery. Photographic recording would have to be used if speed of measurement was desired. It is clearly possible to elaborate this method so as to allow any particular range of angle to be examined in detail. Our method is based on this type of presentation but is arranged so as to overcome the difficulties and to eliminate the necessity of photographic recording.

Description of the Apparatus

Our method is based on an electromagnetic recorder of the type manufactured by our firm. This is a centre zero moving coil instrument, the pointer of which carries a platinum-iridium stylus which is drawn across "Teledeltos" recording paper. This recording paper consists of a metallic backing upon which is deposited a layer of carbon which has a combustible chemical film sprayed on the other surface, leaving a matte grey finish. The metallic layer is held against an earthed metal contact plate which is connected to the negative side of a D.C. supply with a potential of a few hundred volts. The other side of the supply is taken to the stylus. Current passed through the paper burns away the top layer, exposing the carbon below and leaving a thin black trace of outstandingly good definition. The paper is gripped between rollers which are driven by a motor so as to draw the paper past the stylus.

A recorder of this type was modified to our requirements by removing the motor and replacing it by a gear train driven by a selsyn capable of producing considerable torque. The selsyn was connected to a similar selsyn, acting as a transmitter of angle, which was geared to the aerial shaft. The aerial was rotated by a motor, the supplies to which could be reversed together with the selsyn connection so that both directions of rotation could be used. The aerial was connected to a microwave superheterodyne receiver consisting of a crystal mixer, 30 Mc/s. I.F. amplifier, diode second detector, and a D.C.

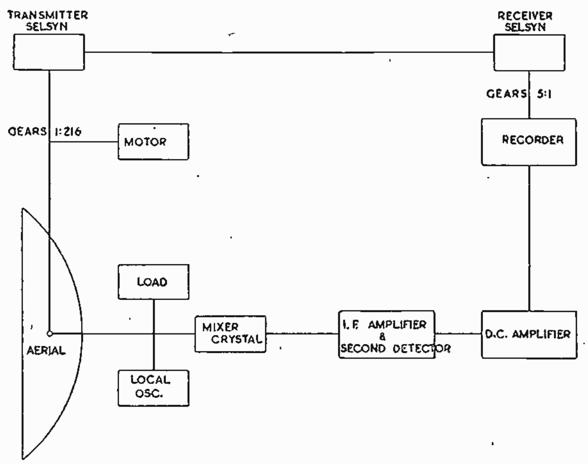


Fig. 1. Block diagram of complete apparatus

* Henry Hughes & Sons, Ltd., Ilford.

amplifier designed both to work into the 5,000Ω impedance of the recorder coil, and to allow the pointer to be biassed fully over to one side. This was done to make use of all the available deflection. A block diagram of the apparatus is shown in Fig. 1.

The apparatus was developed primarily to test 3 cm. radar antennae designed to produce beams with azimuthal angles of the order of 1°. In the arrangement we used, the aerial was geared up to the transmitter selsyn with a ratio of 216 : 1 and the receiving selsyn was geared down to the roller with a 5.1 ratio. These ratios were determined only by the availability of high-grade gears because the paper displacement corresponding to 1° rotation is not critical. The diameter of the paper drive rollers was 2.39 cms., so 1° of aerial rotation corresponded to 0.9 cms. displacement of the paper. Fig. 2 shows the arrangement of the recorder and Fig. 3 the aerial gear train, selsyn and motor. Fig. 4 shows a cheese aerial under test and Fig. 5 the general arrangement of the apparatus at the receiving station.

Electrical Details

The transmitter used was a high voltage reflex klystron worked from carefully stabilised voltage supplies. Sufficient attenuation was used between the generator and the transmitting aerial to ensure that reflections due to changes in the environment should not alter the frequency. At the receiver end a conventional waveguide mixer was used, together with a second carefully stabilised reflex tube. The I.F. amplifier was conventional but the D.C. amplifier may be worth describing. The diode second detector gave a negative going output, one side of which was earthed and, as has already been stated, it was required to bias the stylus fully over to one side. The amplifier circuit is shown in Fig. 6. It consisted of a long tailed pair used with a saturated pentode as a common cathode impedance. The valves used were CV173 connected as triodes. Owing to the fact that the grid of the input valve was earthy, the negative return had to be well below earth potential. The grids of the long tailed pair were connected to potentiometers across the H.T. supply which was set so that V_2 took less current than V_1 and the coil was fully deflected. When the grid of V_1 is driven negative the potential of the anode of V_3 rises and with it the cathode potential of V_2. V_2 then takes more current and the circuit gives a push-pull effect. The circuit is very linear and stable. The grid of V_2 is earthed through a 2 μF condenser to eliminate hum.

The amplifier gave the 10 ma needed for full-scale deflection (2 cms.) for 4.5 volt input.

Before any measurements were made the apparatus was carefully checked to make sure that it was linear overall. Once this had been done the signal levels at signal mixer and second detector were maintained close to the values at which a linear response had been found, so that no non-linearities were introduced during the tests.

Results

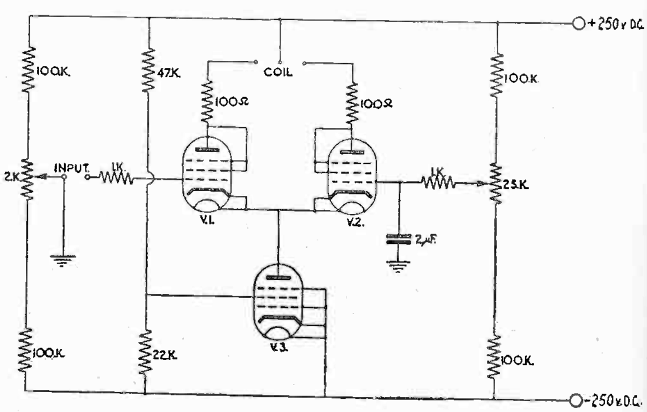
A typical record is shown in Fig. 7, which only covers a few degrees round the main lobe. The picture is slightly distorted due to the fact that the stylus arm is only 6 cms. long. The simplest method of taking measurements from the record is to use a protractor with a radius equal to the length of the stylus arm. This enables one to measure the deflection and to identify the point on the base line corresponding to a point on the curve in one operation.

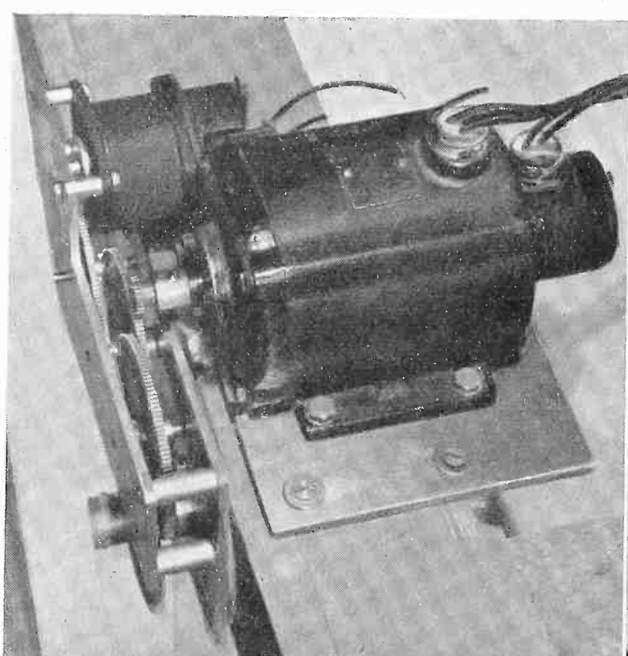
A record of the complete polar diagram of a "Cheese" antenna could be obtained in 2 seconds. This means that a large number of diagrams could be plotted in a few minutes and mean values obtained

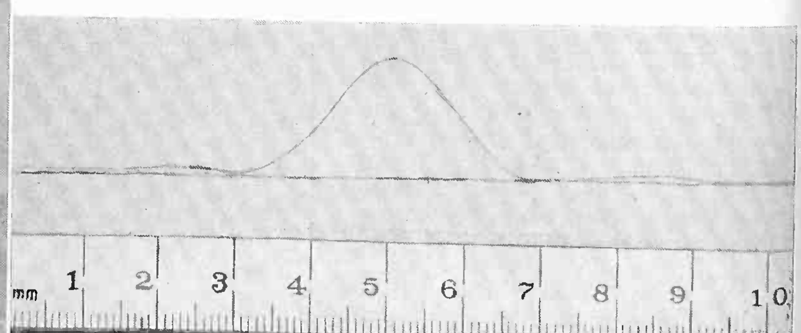
Fig. 3 (*left*). Aerial Gear Train, Selsyn and Motor

Fig. 6. Circuit diagram of D.C. amplifier

Fig. 7 (*below*). A typical record, covering about 8° rotation







for the important quantities which in our case were the beam width between quarter power points and the magnitude of the largest side-lobe as a percentage of the maximum field in the main lobe. When sufficient observations had been obtained at a given frequency, the transmitter and local oscillator were tuned to a new frequency and further diagrams made. In this way a permanent record of the performance over a whole frequency band could be obtained in an afternoon, whereas older methods would have taken a week.

Table 1 illustrates the consistency of the readings.

Table I

Observation	Beam width °	Side-lobe %
A	1.90	5.00
B	1.95	4.70
C	1.92	4.65
D	1.92	4.85
E	1.93	4.85
F	1.93	4.50
Mean	1.93	4.75

The measurements on the side-lobe are naturally less accurate than those on the main lobe because the deflection is only of the order of 1 mm. Even so the largest discrepancy is only about 5 per cent.[1]

Conclusion

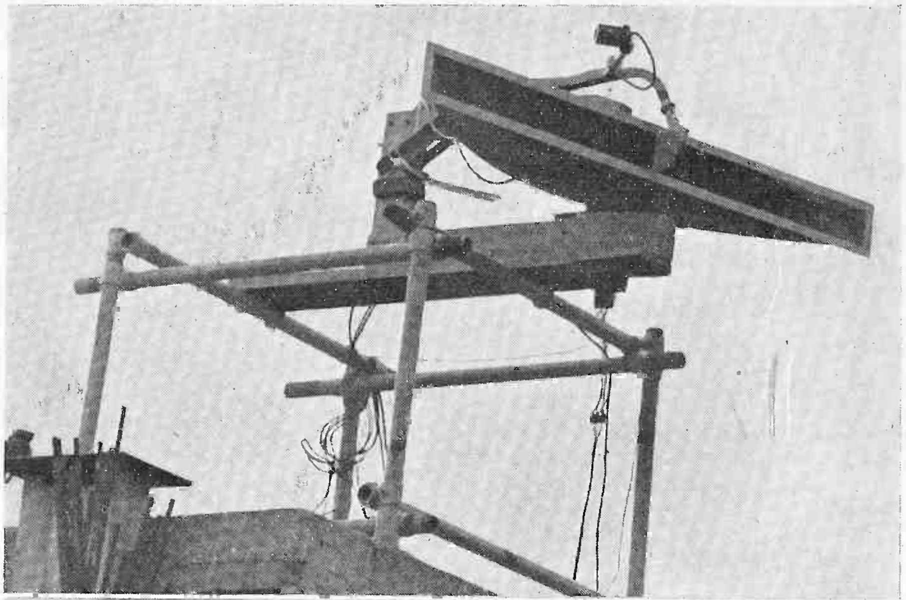
A rapid and convenient method of measuring aerial polar diagrams, which presents the results in a permanent form, has been described. The results obtained exhibit a very high degree of consistency. Two minor disadvantages, the slight distortion of the picture, and the rather small maximum deflection will be overcome by a new recorder with a 10 cm. stylus arm, giving a total deflection of about 4 cm.

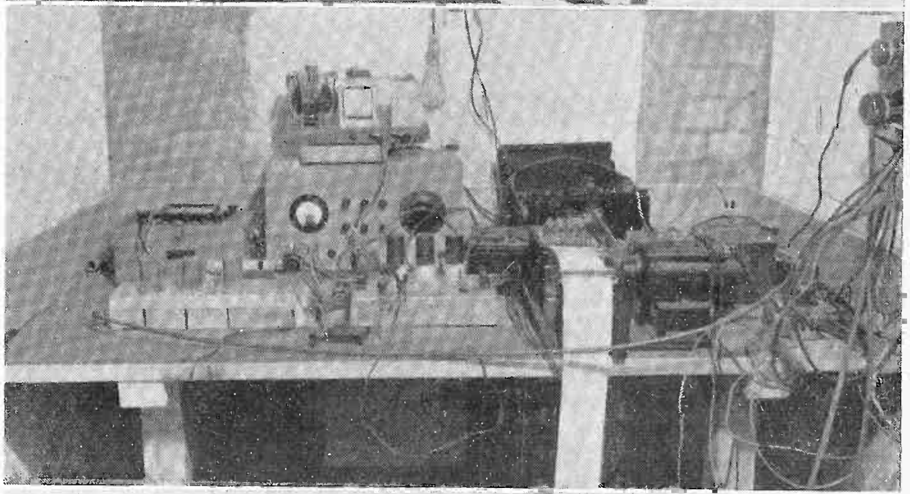
This method would seem to have more general application than that described; for it is capable of plotting an independent variable, against any dependent variable which can be converted into a rotation.

Acknowledgments

It is a great pleasure to acknowledge the skilful assistance of Mr. P. R. Bunce, who made the experimental apparatus and Mr. K. A. B. Gilfillan who assisted in the measurements. Our best thanks are due to the management of Henry Hughes & Sons, Ltd., for permission to publish the paper.

[1] Clayton, Houldin et al *J.I.E.E.* Part III, 93, 97, 1946.





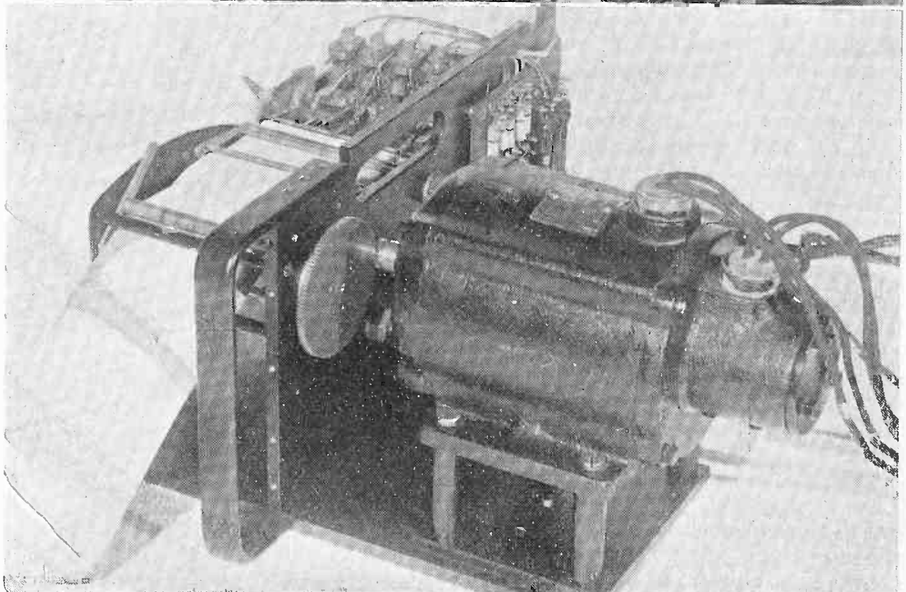


Fig. 4. "Cheese" aerial under test

Fig. 5. General arrangement of the apparatus at the receiving station

Fig. 2. Arrangement of the modified Recorder used in the experiments

The Skiatron or Dark Trace Tube

and its Applications

By G. Wikkenhauser*

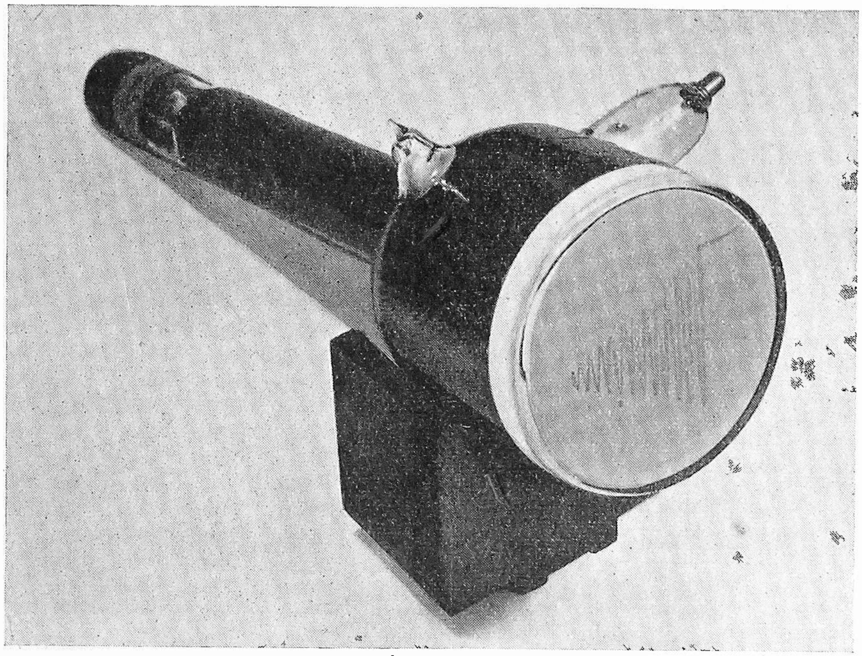


Fig. 6. British dark trace tube with trace on screen

DR. A. H. ROSENTHAL, of the Scophony Laboratories, suggested in 1938,[1] the use of a new kind of cathode-ray tube for television reception, or in general for short duration recording of electrical signals. In this tube the ordinary fluorescent screen is replaced by a screen consisting of alkali-halide crystals, which become darkened under electron bombardment.[2]

The effect of this tube is based on electron opacity and it was discovered in the early days of cathode-ray research, *i.e.*, in 1894 by E. Goldstein,[3] that various alkali-halide crystals, if subjected to cathode rays, become intensely coloured.

R. W. Pohl[4] investigated the effect further and recently Mott and Gurney[5] also made a detailed study of the behaviour of alkali-halides under electron bombardment.

The reader is referred to these references for detailed information on this effect; here the author is only attempting to convey a simple picture of what might be taking place.

If a thin layer of alkali-halide crystals is bombarded with electrons, some electrons are displaced from the halides and secondaries are produced. These free electrons take up position in the faults of the crystal lattice and they vibrate at frequencies corresponding to certain wavelengths of the visible light spectrum. This vibration, of course, causes absorption of this wavelength, the result of which is a dark trace on the originally semi-transparent crystal layer. The colour of this is the complementary colour of the absorption.

The wavelength of absorption depends on the material used, the most common being potassium chloride. The absorption of this is in the green region of the visible spectrum, therefore the dark trace appears as a magenta colour; in other materials such as potassium bromide the absorption occurs more in the bluish range of the spectrum, and the trace is brownish. In sodium chloride the trace is of a more orange colour.

If the screen on which this trace is formed is irradiated intensely with light or heat rays or both, due to the absorption of further energy by the electrons, they leave the "holes" and tend to revert to their original position, forming again the alkali-halide with the full number of electrons, therefore the dark trace disappears.

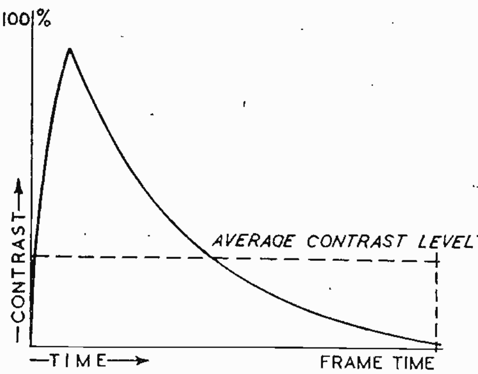


Fig. 1. Fading characteristics of trace during television frame time

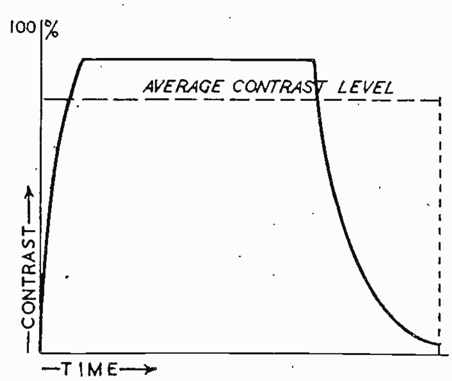


Fig. 2. Ideal fading characteristics

Before the War, Dr. Rosenthal succeeded in showing a television image received on a "Skiatron" tube, of the standard 405-line interlaced television transmission of the B.B.C., although the picture was not quite satisfactory. It was recognised at that time that much work would be required to achieve the necessary perfection. Unfortunately work on this application had to be interrupted due to the War intervening, since at the commencement of hostilities television transmissions in England ceased. The images received were not satisfactory mainly because of insufficient contrast. This was due to the fact that the trace remained on the screen too long, and disappeared only gradually. The time of disappearance of the trace is a function of the amount of the original discolouration, darker traces requiring a longer time, and to prevent blurring of successive pictures (which were transmitted at the rate of 25 pictures per second) it was necessary to limit the darkening to very faint traces.

Further, the contrast is weak in the picture because the dark discolouration dies away according to

* Scophony, Ltd.

approximately an exponential function and, of course, the human eye during one picture frame sees the integrated effect over the frame scanning time. Due to the fact that a dark trace is produced which fades away gradually, the contrast in the received picture is very low (*see* Fig. 1).

However, this initial experiment proved that tubes of this description using extraneous illumination should be capable of providing sufficient screen illumination even for large projection.

The question then remained to find ways and means of producing the required contrast for television work. At the same time it was also recognised that the method showed great promise for applications where it would not be necessary for the trace to disappear at a quick rate as in television, say in 1/25 or 1/50 second. Indeed, it was often a great advantage for the trace to remain on the screen for a considerable time in applications where single indications were required.

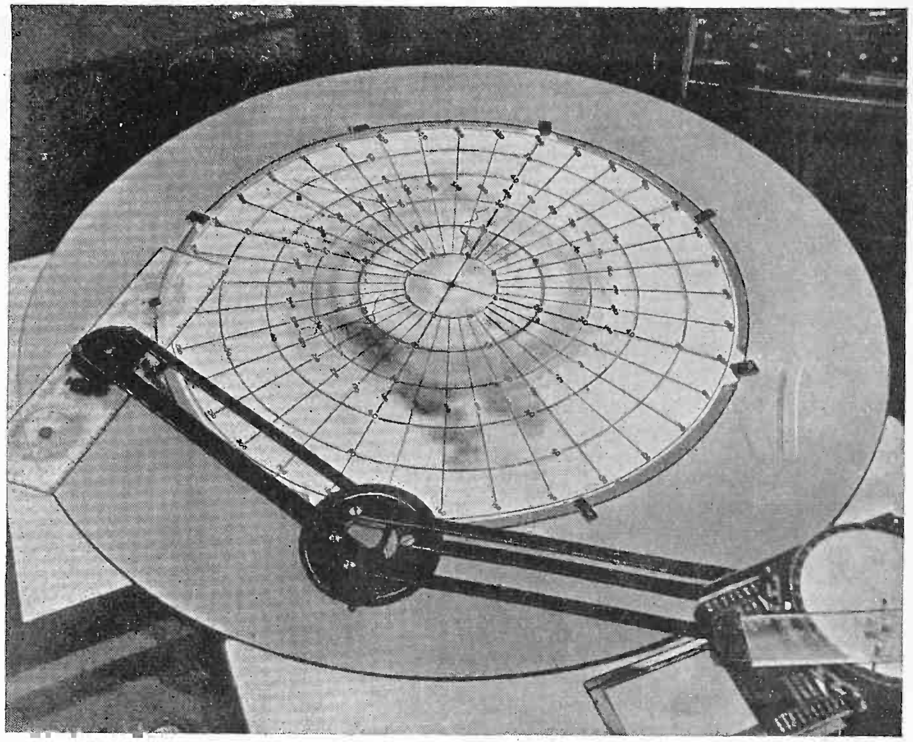


Fig. 4. Screen of the plan position indicator with dark trace tube

The ideal shape of the time curve of the discolouration would be a square shape curve as illustrated in Fig. 2, in which case the trace could remain on the screen with full contrast for the desired length of time, and then it would be erased quickly after the required time. Due to the fact that, as mentioned above, heat and light are essential for the erasure, a certain amount of time must elapse to bring it about. In some cases it is necessary for the screen to reach a temperature, say, of a few hundred degrees centigrade.

During the War in England, and in other countries as well, this tube was used exclusively for P.P.I. work and small and large screen direct view and projected type P.P.I. instruments have been designed and constructed for indicating reflected radar signals from ships, aircraft or any objects reflecting the radar impulses.

It was found that for this purpose it was a great advantage that the signals remained on the screen for a considerable length of time. The obvious advantages of the tube in this application are, of course, that the display can be seen on the tube directly in bright ambient illumination. Further, it was possible to produce large screen projected

Fig. 3. Large screen plan position indicator with "Skiatron" tube, as used by the Admiralty

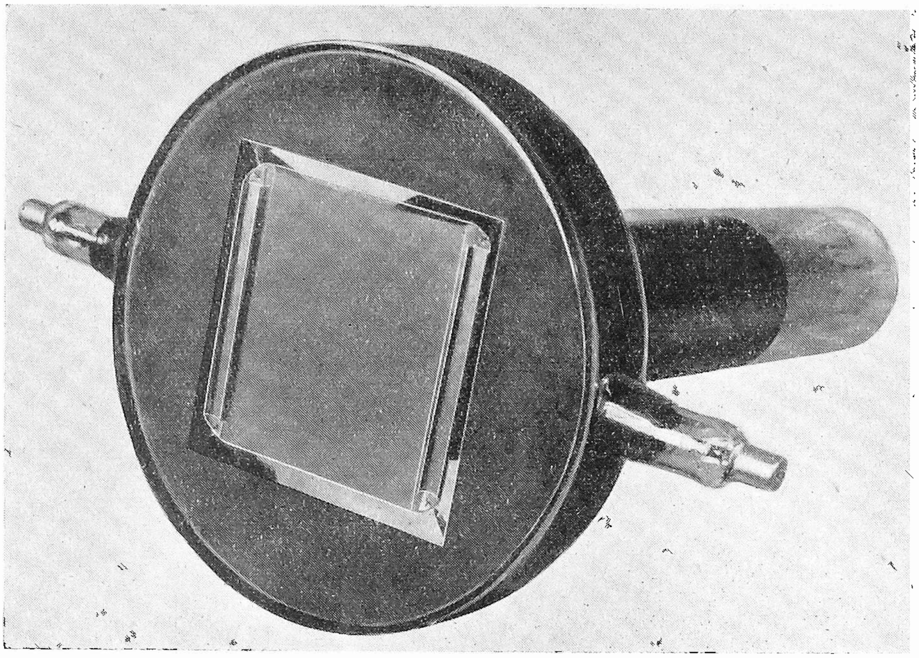


Fig. 5. Dark trace tube developed in Germany

images of the P.P.I. display where many observers were able to watch the display simultaneously. These advantages, apart from the fact that the trace remains for a considerable time on the screen, are of great importance.

Figs. 3 and 4 show the equipment developed and used by the Admiralty for this purpose, these tubes being irradiated with heat and light for cancellation of the trace.[5] Parallel developments have taken place on the same idea in Germany where tubes of similar description were used in various radar equipments

The tubes developed and made in Germany approached to a greater degree, the ideal shape of the time curve of the discoloration because heat was directly applied to the halide screen to cancel the trace. The method was as follows: On a thin sheet of mica a thin layer of tungsten film was deposited, thin enough to be transparent to visible light, but at the same time electrically conductive. The tube was not heated normally during the recording, but only when it was desired to cancel the trace was a current passed through the tungsten film which heated up quickly, thereby producing a temperature rise in the alkali halide. According to the German specification it was possible to achieve erasure, even of a very dark trace, between 5 and 10 seconds.

Fig. 5 shows a tube of this nature made in Germany by Telefunken. The metal caps on the sides of the tube provide connexion to the tungsten film.

Possible Applications for "Skiatron"

Most of the possible applications of the dark trace tube are self-evident, but generally they fall into two categories. For research and engineering applications the tube can be used as an oscilloscope to provide short time recording of transient non-recurring electrical phenomena. This is shown in Fig. 6 which illustrates the British tube made during the War for radar applications with a trace of a damped 25-cycle wave.

The tube provides immediately a visible record which can be kept on the screen until erased and examined in detail at leisure. This record can, of course, be traced on paper or photographed with a simple camera. In transient recording equipment with fluorescent screen great care has to be taken to synchronise the camera shutter to the electrical phenomena. High speed lenses and films are required, therefore the advantages of the use of the "Skiatron" electron-opacity tube for transient recording are obvious. For most of the applications it was found that direct observations were sufficient.

The "Skiatron" large screen P.P.I. used during the War for aircraft tracking purposes, appears to have found its way into post-war civil aviation and according to the All-Weather Flying Centre[6] at Wilmington, Ohio, a large screen "Skiatron" will be an essential part of the equipment of an aerodrome control installation. The track of every aircraft within a radius of 50 miles round the aerodrome will be recorded by a search "Skiatron" projector indicating the track of the aircraft to the controllers.

There are other applications which are, of course, essentially the same as those for transient recording, which come into the field of facsimile transmission and reception, or instantaneous recording of a single frame television image.

The speed of operation not being limited in any way by the inertia of the facsimile scanning mechanism, provided a sufficient bandwidth is available for the transmission, high definition images can be transmitted and received considerably quicker than with the present-day methods.

For television applications, although the electron opacity is very attractive, insofar that practically unlimited screen illumination can be achieved, the length of time required to erase the picture and the lack of contrast due to the exponential decay of the dark trace, excludes the use of this method at present. Further research is necessary to ascertain whether a method of erasure quick enough for television is possible, or alternatively if the contrast can be increased by other methods. Work is going on in both directions.

The author would like to express his thanks to the Admiralty for the photographs showing the large screen P.P.I. as used during the War.

References

1 British Patents Nos. 513,776; 514,155; 514,776.

2 Rosenthal, A. H.: "A System of Large Screen Television based on certain Electron Phenomena in Crystals," *Proc. I.R.E.*, Vol. 28, No. 5, 1940, p. 203-212.

3 Goldstein, E.: "Uber die Einwirkung von Kathodenstrahlen auf einige Salze," *Ann. der Phys. u. Chem.*, Vol. 54, p. 371, 1895.

4 Pohl, R. W.: "Electron Conductivity and Photochemical Processes in Alkali Halide Crystals," *Proc. Phsy. Soc.*, Vol. 49, p. 3, Aug., 1937.

5 "Electronic Process in Ionic Crystals."

6 Hotz., R. B.: "Radar Traffic Control System developed at All-weather Center," *Aviation News*, Feb. 3, 1947 (Transport Section).

Vibrator Beam Switching

A Method of Recording Simultaneously Two Related Biological Phenomena of Low Frequency Using a Single Beam Cathode-Ray Oscilloscope

By E. S. McCALLISTER*

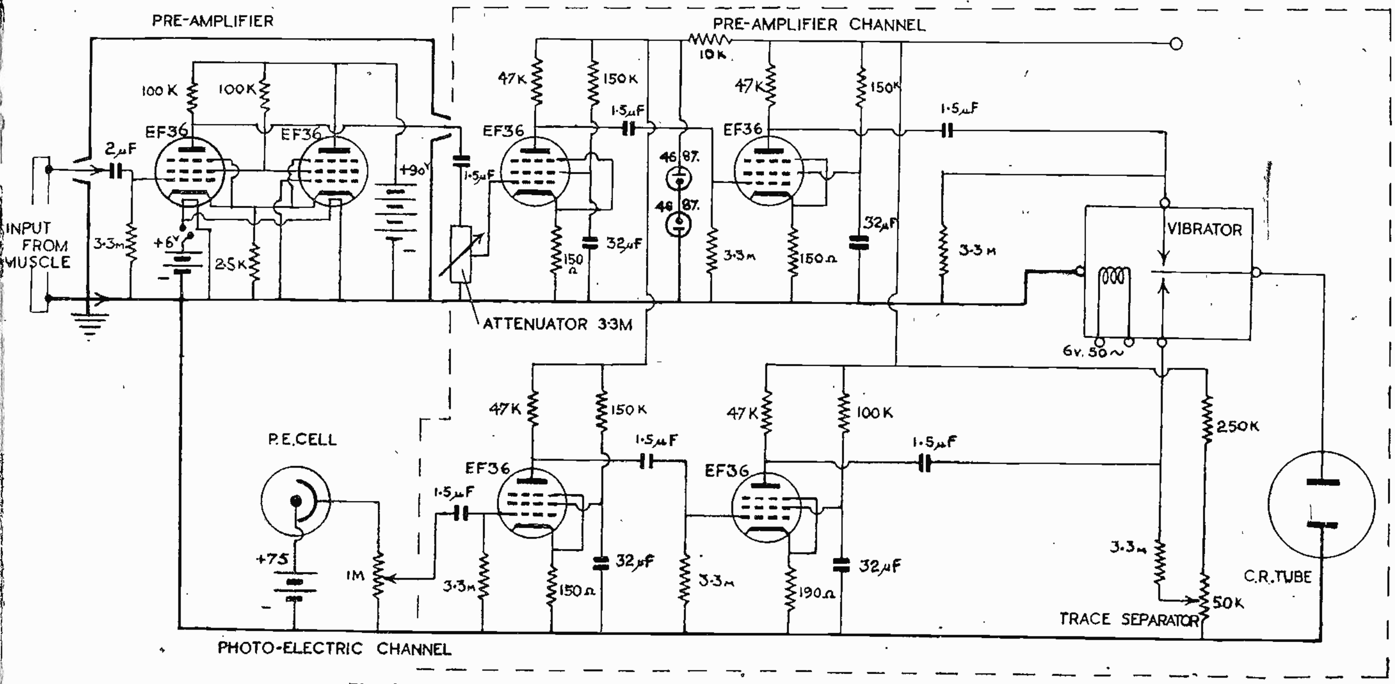


Fig. 1. Complete circuit diagram of apparatus for double trace recording

IN the course of an investigation of the properties of intestinal smooth muscle, which is reported in the *Journal of Physiology*,† the need arose for a convenient method of recording simultaneously (a) the action potentials, possessing amplitudes of the order of 20µV to 1 mV, with a recurrence frequency of approximately one every three to five seconds, and (b) the mechanical contractions occurring rhythmically in that muscle. The method herein described was developed for that purpose, and is applicable to small muscles, exerting very slight pulls.

As a basis for the construction of this apparatus a Mullard Cathode-Ray Oscillograph Type E.800 was chosen. This instrument was subsequently modified to provide two separate channels of amplification, one for each phenomena. Particular care being taken to ensure that the inter-valve coupling time-constants ($C \times R$) are large compared with the duration of the phenomena under test, and that the H.T. supply (300 V) is obtained from a low impedance source. This minimises the effect of extraneous coupling between stages. Each amplifier channel, in conjunction with the cathode-ray tube, provides a sensitivity of 1 mV/cm. with an overall sinusoidal frequency response which is flat within 3 db. between the limits of 0.2 c/s. and 40 Kc/s.

Mechanical Switching to Combine the Two Phenomena

The outputs from the two amplifiers are fed into a mechanical vibrator (Wright & Weaire Type ACD/6) which is essentially a vibrating reed forming the moving contact of a single-pole double-throw switch, the vibrating reed being actuated by means of a solenoid placed close to it and supplied from a 6-volt 50 c/s. source. This connects the vertical deflector plates of the cathode-ray tube alternately to each amplifier at a frequency of 100 c/s.

Owing to this "chopping" frequency being high compared with the frequency of the phenomena being recorded, a faithful reproduction of the relationship between each phenomenon appears on the screen of the cathode-ray tube.

Separation of the Base-Lines

In order that each phenomenon should appear as a separate function on an individual base-line, provision is made whereby auxiliary bias is applied to the output of one amplifier relative to the other, so that when contact is made to the biased channel the mean position of the luminous spot is deflected in the vertical plane by virtue of the steady D.C. potential. The two base-lines are separated by an amount which is dependent upon the value of the bias applied. For convenience this bias voltage is made variable in order to cope with the various amplitudes of waveform to be examined.

Phase distortion between the two channels was tested by applying a rectangular pulse of similar recurrence frequency as the biological phenomena, simultaneously to both inputs and photographing the response on the cathode-ray tube. This measurement showed that

* Electro-Medical Section, Philips Electrical Ltd.
† Author: N. Ambrache : Manuscript in Press.

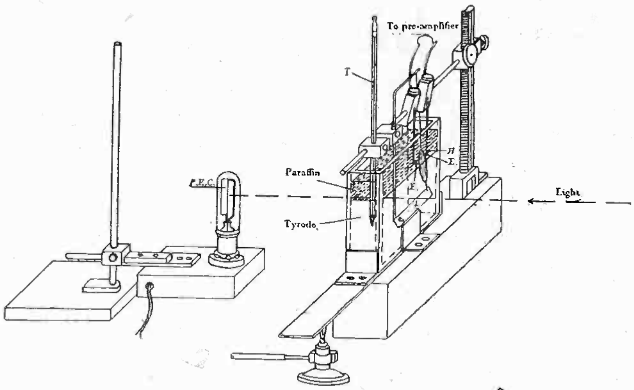


Fig. 2 (*left*). **Set-up of apparatus for converting muscle movement into electrical variations**

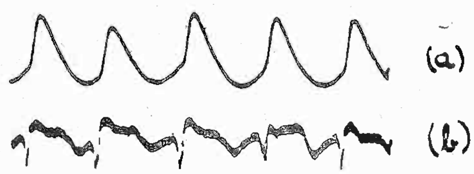


Fig. 3 (*below*). **Typical double-wave trace obtained**

inter-channel phase distortion did not exist.

Recording the Action Potentials

As the amplitude of action potentials to be measured are sometimes of the low order of 20 μV, an additional battery operated head amplifier has been added to one of the two channels. This takes the form of a conventional resistance-capacity coupled H.F. pentode (V_1, Mullard Type E.F. 37) the addition of this valve giving an increase in gain of some 50 times, thereby raising the overall sensitivity to approximately 20 μV/cm. The valve V_2 acts as a stabilising agent and serves to minimise the effect of base-line fluctuations.

The input to the amplifier is single-ended, all stray pick-up being overcome by housing the head amplifier, gut and auxiliary apparatus in a heavily screened box. Fig. 1 shows the basic circuit arrangement.

The attachment of the electrodes to the muscle in a layer of paraffin is described in the aforementioned biological paper.

Photoelectric Recording of Contraction

The physical movements of the intestine are converted into electrical energy photo-electrically, Fig. 2. A beam of light from a small flashlight bulb in a collimator fitted with an iris diaphragm, is directed onto the light sensitive electrode of a photo-electric cell (Osram Type CMG.25). Interposed between the light source and the cell is a parallel-sided glass bath containing the preparation in physiological saline. The gut is tied to a very light ivorine shutter (inside the bath), the movements of which in the beam of light cut off a proportionate amount of the light reaching the cell. The ultimate result is a voltage-variation which is subsequently amplified by the second amplifier in the E.800 and appears on the alternate base-line of the cathode-ray tube.

The two phenomena can either be viewed simultaneously on the screen of the cathode-ray tube, using a slow horizontal traverse, provided by time-base circuitory in the E.800, or they can be photographed at close quarters on a transversely moving 35 mm. film such as Kodak R.55 or "Fluorodak."

Calibration

The time axis is calibrated by interrupting the light beam at fixed intervals, by means of a Palmer time-clock, which is inserted in series between the collimator and its accumulator.

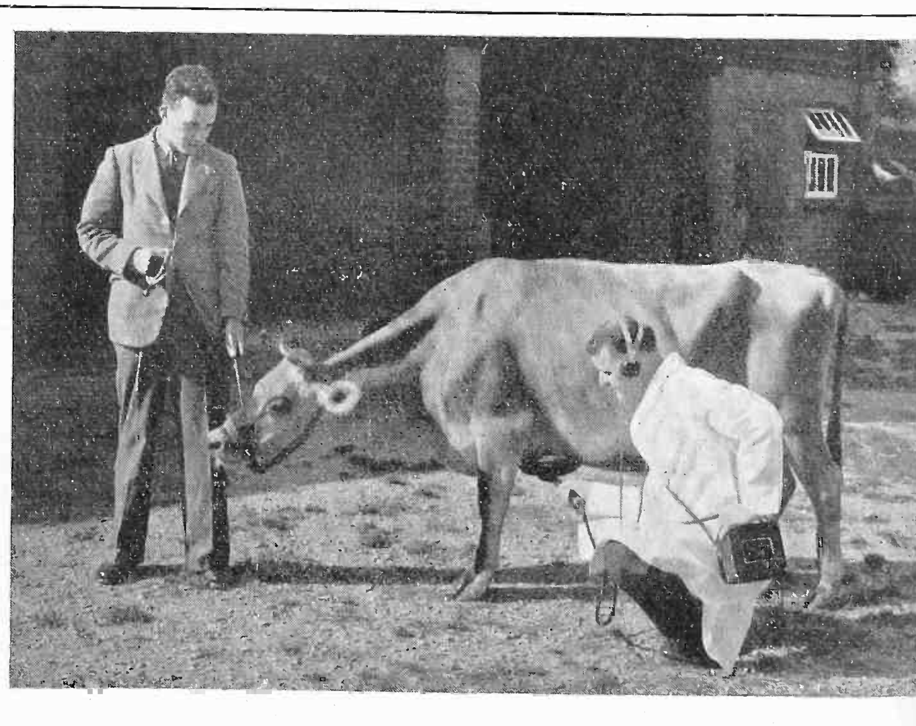
Amplitude calibration is accomplished by momentarily applying a known D.C. potential from a calibrated attenuator. The film being in a stationary position during this action, the voltage change produced appears as a vertical line, the peak to peak value being equal to the voltage applied.

This work was carried out in the Department of Pathology, Guy's Hospital Medical School.

Electronics in the Farmyard

A NEW use for the war-time mine locator has been found in veterinary surgery, and the photograph shows a cow being sounded for barbed wire which it has swallowed. The "Cintel" Metal Detector shown operates on the same principle as the Mark IV Mine Locator described in ELECTRONIC ENGINEERING for February, 1946, but is considerably lighter. The amplifier, which weighs only 6½ lb., is slung over the shoulder from a strap. In addition, the detector will locate the run of 6-in. pipes to with a few inches at depths up to 2 ft. 9 in. below the ground, and will also indicate the presence of both metallic and non-magnetic bodies in timber up to a depth of 9 in.

—Photo by courtesy of Cinema Television Ltd.



The Televisor — *Further Notes and Queries*

For an announcement regarding copies of the booklet: "A Modern Home Built Televisor", see p. 1 of this issue.

SOME queries not listed below will be found on p. 352 of the November issue. The majority of readers have noted the coil winding data which was given on that page, but it is reproduced here for the benefit of later purchasers of the booklet.

Coil Data

L.1 – L.7 and L.9 – L.14 are wound with 32 or 34 g. D.S.C. copper. Turns are held in place with Certofix. The tuned windings are nearest the moulded flange.

In addition: The coils are close wound; the formers are approximately $\frac{3}{8}$ in. outside diameter and 5/16 in. inside.

Choke L.8

The fact that this has been wound on a 1 meg. resistor as a former has puzzled several constructors, and this should have been explained more fully. The resistor is not marked in the circuit as it has no useful function; in fact, a length of paxolin tube of the same size would serve equally well.

The coil is disposed centrally in a hole in the screen through which it passes. This screen is the right-angled one in the photograph of Fig. 5.

Valves

The following have been tested and approved as substitutes:

For Mazda T.41, Mullard EN.41
For Mazda Pen. 45, Osram KT.41
For Mazda Pen. 46, Osram KT.45
For Mazda UU.8, Cossor 45.IU
For Mullard EL.33, Osram KT.61
For Mullard EBC.33, Mullard TDD.4*

* With separate heater choke from 4 V supply.

Circuit Corrections

Some lines were omitted from the circuit diagram, or are ambiguous. The following corrections should be made:

Fig. 6. V.8 can be connected as shown, or as in the photograph of Fig. 10, *i.e.*, with suppressor and screen joined to earth. The valve is intended to act as a high-mu triode.

Fig. 17. The suppressor of V.12 should go to earth, as in Fig. 18.

Fig. 23(*a*). The resistance chain R.81 – R.86 is better connected on the rectifier side of R.80, *i.e.*, directly across the rectifier. The other connexions are unchanged.

Fig. 23(*b*). The screen of V.20 should be connected to the H.T. line, *i.e.*, to the junction of T.4 and R.92.

Resistor Values

R.53 on p. 43 should be 10K.
R.57 on p. 43 should be 56K.
R.54 on p. 43 should be 0.22M.
R.25 on p. 24 is 3.3K as specified.

Power Consumption

Sound Unit 40 mA.
Vision Unit 56 mA.
Time Base, etc., 140 mA.
Focus Coil 15 mA.

Smoothing Circuit

The components of the smoothing circuit in order from left to right at the bottom of the chassis in Fig. 25 are: C.65, Ch.9, C.66, Ch.10, C.67.

Leads

A common lead for the cathode and heater is not recommended owing to the risk of hum from the voltage drop in the lead.

The modulation lead from V.8 can be run close to the supply leads if desired.

The leads to the gain control in Fig. 9 are taken from the feed-through capacitor C.2, which is shown at the top of the photograph of Fig. 5.

Chassis Diagram, Fig 21

The slot shown at the lower edge of the chassis drawing in Fig. 21 should start $3\frac{1}{4}$ in. from the edge of the chassis and not 3 in. as shown.

Interference Suppression

The circuit given in Fig. 7 on p. 327 of the October issue may be connected across the grid feed of the cathode ray tube to provide vision interference suppression.

The diode shown in the diagram (D.1) should be fed from the "B" heater supply.

Suppression on sound is best obtained by putting a separate double diode (Fig. 5, p. 326) for rectification and suppression and feeding the output to the grid of V.11. C.30 should be connected direct to the detector anode and R.47 taken to earth. The output from the limiter anode will then be taken direct to the grid of V.11.

E.H.T. Supplies for Cathode Ray Tubes

E.H.T. supplies for cathode ray tubes are required to provide a smoothed output of several thousand volts, and there is a trend particularly in post-war American design to derive the E.H.T. from a high-frequency source. The source may be the scanning generator causing line deflection, or it may be a separate oscillator specially arranged for the purpose.

In either event the design avoids the expense of the copper and iron of a mains frequency transformer. It also greatly simplifies the question of smoothing, since the smoothing condensers can be of much smaller capacity. With, however, the use of a scanning generator the E.H.T. is dependent on the scanning amplitude and consequently any alteration in the scanning amplitude must be followed by a readjustment of the beam focus. If a separate oscillator is used to avoid this difficulty, another difficulty may arise in the interference of the oscillator with a local oscillator that may be associated with the receiver for mixing purposes, so that disturbing beats are superimposed upon reception.

Where this difficulty arises it is proposed not to employ the two oscillators in the receiver but to derive the mixing oscillations, either as the fundamental or another selected harmonic, from the oscillator arranged to supply the E.H.T. for the cathode ray tube. Alternatively both oscillators may be employed but the oscillator supplying E.H.T. is run at a sub-harmonic of the local oscillator. In this way shifting patterns which may appear on the screen of the cathode ray tube and distract vision are avoided, although the simplicity and other advantages attendant with a high-frequency source of E.H.T. are retained. The principle may be used not only where the television receiver incorporates a superheterodyne oscillator, but where such an oscillator is present in an associated radio broadcast receiver.

Communication from Electrical and Musical Industries, Ltd.

A Sensitive Circuit Breaker for Instrument Protection

By A. BORUP

PROTECTION against overload of D.C. instruments has been left almost entirely to the conventional electromagnet circuit breaker or the fuse.

Neither of these methods is applicable when instruments of 50 or 100 microamps. are to be protected.

Faced with the problem of a high breakage on this range of instrument at a period during the early part of the war, when new instruments and repairs were alike hard to get, it was decided to investigate the possibility of keeping the instruments in commission by an effective protective device.

For this device to be a practical proposition size and cost had to be kept to a minimum.

Experiments with a very sensitive home-made electromagnetic relay showed that contact problems and mechanical instability were limiting factors, and that a new approach to the problem had to be made.

It was decided to try a device using a gas triode as a sensitive element, and it was the successful development of this idea which provided a satisfactory answer to the problem.

Theory of Gas Triode Circuit

In order to meet the requirements of small size and low cost it was appreciated that a wholly A.C. energised device was desirable as rectifying components could be eliminated and the problem of automatically resetting the circuit would be eased considerably.

The theoretical circuit diagram is shown in Fig. 1.

V is a gas triode which has an alternating anode voltage V_a applied through the operating coil of the electromagnetic circuit breaker C.B. An alternating voltage V_g, 180° out of phase with V_a, is applied to the grid through a resistance R.

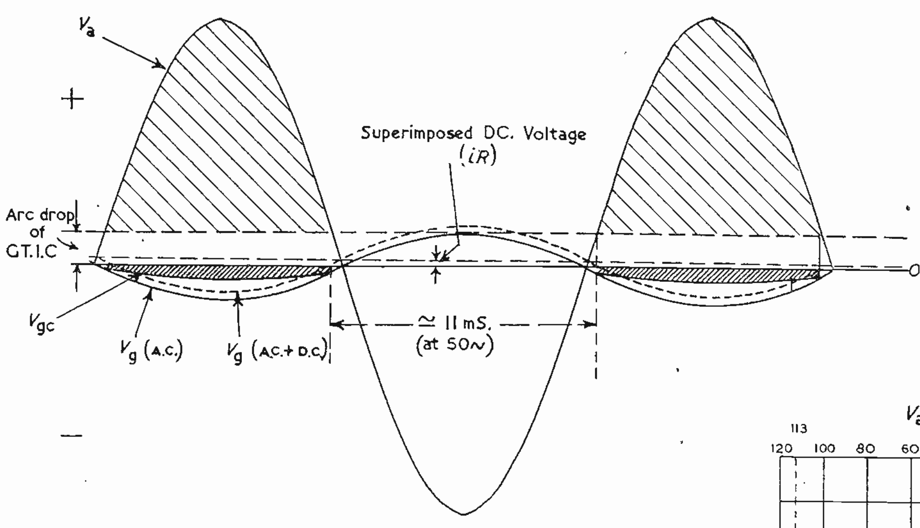
If V_g is sufficient to maintain the grid more negative than the critical grid voltage V_{gc} no current will flow in the anode circuit.

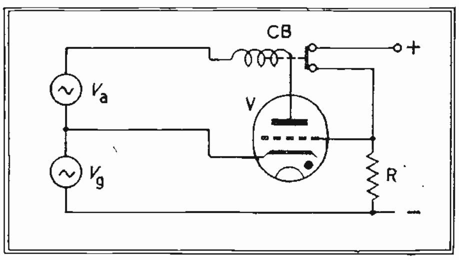
If a current I flows in R making the grid end of R positive enough to bring the net voltage at the grid more positive than V_{gc}, the valve will ionise during positive half-cycles of V_a and current will flow in the coil of C.B. The opening of the circuit breaker contacts will then interrupt the current I. If now the source of I is removed, or the value reduced so that IR is too small to trigger the valve, the circuit breaker can be reset.

It was found experimentally that $V_a = 80$ V R.M.S. was sufficient to operate the particular circuit breaker used with a reasonable safety margin.

Reference to the control curve for the valve used showed that at $V_a = 80\sqrt{2}$ or 113 V the critical grid voltage was -5.5 V corresponding to 3.9 V R.M.S. But experiment showed that a value greater than 6 V was necessary to hold off the gas triode. The reason for this discrepancy is a simple one: the assumption which is made, that V_{gc} is proportional to V_a is not true, and would only be true if the projection of the straight portion of the control characteristic passed through the point $V_a = 0$, $V_g = 0$. In fact, the curve is displaced appreciably from this position by the effect of contact potential. A graphical explanation of the foregoing is given in Fig. 2 and a simple method of determining the discrepancy or the critical value of V_g is shown.

Another graphical construction, Fig. 3, shows the essentials of operation of the circuit. The shaded portions of the positive half-cycles of V_a show the voltage available for operating the circuit breaker and for supplying the transformer voltage





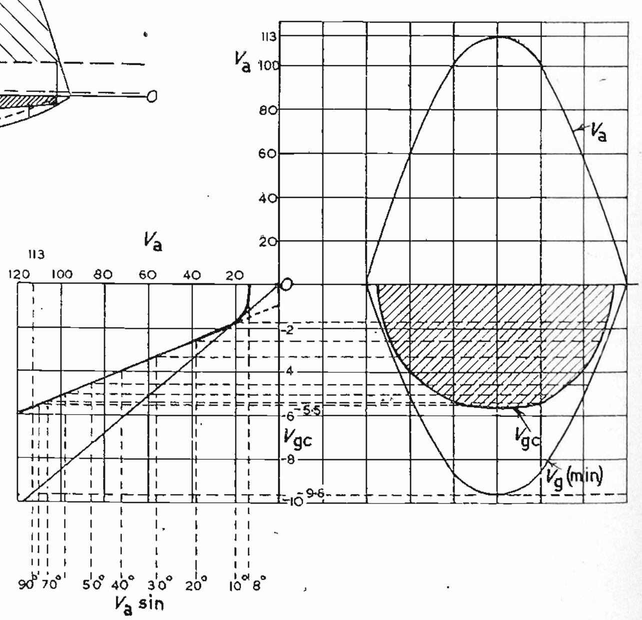


Fig. 1. (*left*) Theoretical circuit diagram

Fig. 2 (*right*). Graphical construction to find the critical value of Vg

Fig. 3 (*above*). Diagram to illustrate principle of circuit operation drop. The V_{gc} curve is plotted in relation to it and a suitable value of V_g is shown. The dotted line shows the voltage applied to the grid when current is flowing in R.

The sensitivity of the circuit breaker can be seen to be a matter of some importance if rapid operation is desired. If it requires appreciably more than the total energy available during one positive half-cycle the operation becomes dependent on integration of energy over more than one cycle. The minimum operating time in these circumstances cannot be less than 20 milliseconds. On the other hand, if the energy required is small compared with that available during one positive half-cycle sensitivity is largely wasted because though the minimum operating time is reduced the maximum time is largely determined by the time during which the gas triode cannot be ionised—an interval of some 11 milliseconds. If the cost of electromagnetic circuit breakers varies directly with the sensitivity an optimum value should be found between these two extremes.

Practice

Fig. 4 shows a practical circuit diagram of the device.

It will be noted that a resistor of 10,000 ohms is inserted in the grid circuit of the GT1C. This is to prevent excessive current flowing in the valve

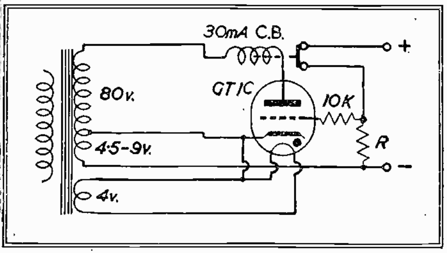


Fig. 4.

in the event of excessive voltages being generated across R or in case of accidental open circuit of R.

The electromagnet circuit breaker used has a coil resistance of approx. 800 ohms, nominally 30 mA rating and has separate coil and contact connexions. The coil resistance is sufficient to limit the peak anode current to a safe value. The heater is tied to cathode to prevent erratic behaviour due to electrostatic effects.

The transformer used has provision for varying the grid voltage from 4.5 to 8 V in 0.5 volt steps. It is a small component, taking i little more space than the valve.

The device lends itself to the protection of multi-range instruments as well as single range. Fig. 5 shows the connexions for a three-range milliameter. R is split into three sections, that part of the resistance included by the switch S

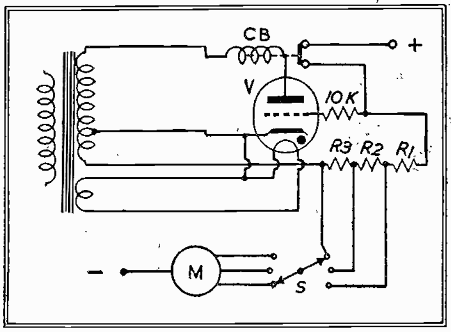


Fig. 5.

satisfying the sensitivity equation for each range.

Sensitivity

The minimum operating voltage drop in R, consistent with reasonable freedom from outside disturbances is adjusted at 0.375 V. This gives a working voltage drop at full scale of the instrument being protected of 0.25 V, allowing 50 per cent. overload before the circuit operates.

The value of R is then given by the equation $R = 250/I$, where R is in ohms and I is the full-scale current in milliamps, of the instrument to be protected.

Response

Using the standard 30 mA circuit breaker set to trip at about 25 mA, and with the armature travel restricted, a number of readings of operating time were taken. The values were between 7 and 21 milliseconds.

Stability

About two minutes elapse from switching on before the circuit reaches its final sensitivity. This initial instability is common to most electronic apparatus and is considered to be important.

Variation of sensitivity with mains voltage changes is more important, and is such that the percentage change of operating voltage is -4 times the percentage change of mains voltage. With mains variation of $\pm$ 6 per cent. operating voltage will vary by $\pm$ 24 per cent., giving the same variation in current sensitivity. This comparatively poor stability has not been troublesome in this particular application of the circuit.

Changes of sensitivity can occur through changes in valve parameters. Variation of control ratio and contact potential, particularly the latter, could affect the sensitivity, and of course, loss of emission could render the circuit inoperative. It is satisfatory to report that valve failure or drift has been of very infrequent occurrence.

Reliability

There are now about 30 of these devices installed, the ranges of the instruments protected ranging from 30 microamps. to 5 A, a great many of them being of the multi-range type. Little trouble has been experienced and most of this has been traced to loose connexions and poor contacts. In a few cases the original valve is still in use after five years.

Improvements

There is one direction in which improvements can be made with little additional cost.

The change in sensitivity with variation of mains input is practically linear over a reasonable range of mains voltage. It follows that conpensation should be possible if a D.C. voltage derived from the mains voltage is applied in the right sense.

Fig. 6 shows how stability is achieved. V_2 is a Mazda D_1, chosen for its small size, R_2 is 100 KΩ and R_3 is 1.2 KΩ, C is 0.5 μF. The A.C. grid

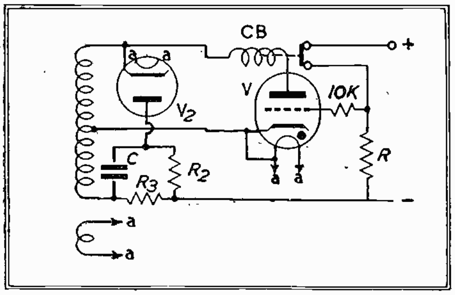


Fig. 6.

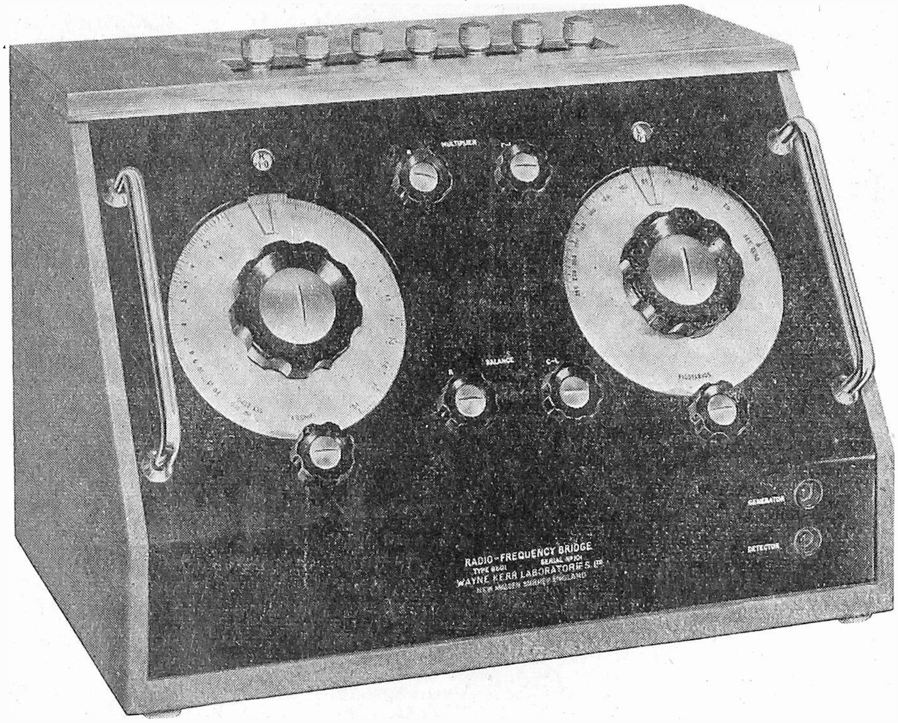
voltage has to be reduced to bring back the sensitivity to the right value.

Compensation is so good that the sensitivity change for $\pm$ 6 per cent. mains variation is reduced from $\pm$ 24 per cent. to rather less than $\pm$ 1 per cent. Over or under compensation can be obtained by altering the value of R_3.

This modification has not been applied to the sensitive circuit breaker in practice as it was considered an unnecessary complication which could not be justified, but the basic circuit can be used for other purposes for which a higher degree of stability is sometimes required.

A New Technique in Bridge Measurements

By R. CALVERT *



WHEN Oliver Heaviside suggested that by increasing the inductance of telephone lines their distortion characteristics could be greatly improved, he was thought to have taken leave of his senses; for inductance was then generally supposed to be the primary cause of distortion. It was not until seven years later that Pupin, an American, put Heaviside's theory to practical test and proved the fallacy of the previous supposition. This reluctance to question "known facts" is often the cause of delaying scientific and engineering progress, but when such beliefs are challenged, the results can be surprising. There has been a recent example of this in connexion with the measurement of impedance at high frequencies.

By common consent a bridge is the most versatile instrument for the measurement of impedance, but bridges have been unsatisfactory at high frequencies owing to the limitations imposed by unavoidable capacities. At the beginning of the war, C. G. Mayo of the B.B.C. Research Department in order to avoid the tedium and labour of making a series of high frequency impedance measurements in the accepted manner, decided to re-examine the possibility of producing a suitable bridge. By substituting a transformer for orthodox ratio arms, he was able to take advantage of the fact that the impedance ratio is proportional to the square of the turns and found it possible to produce low impedance arms capable of accepting heavy capacitative loads with virtually no effect upon their voltage ratio, so long as the leakage inductance of the winding could be reduced to insignificant proportions. The problem of leakage inductance was solved by using a very few turns of concentrically wound copper tape and achieving the necessary self-inductance by winding on a high permeability toroidal core. Using this arrangement, a large capacity across the standard side of the bridge can be effectively cancelled by a suitable trimming capacity across the unknown side, providing only that the unknown is treated as an admittance.

As a result was evolved the first multi-ratio direct reading high frequency bridge, covering a wide range of impedance between 15 Kc/s. and 2 Mc/s. and it proved to be as flexible as an audio-frequency instrument. Further development along the same lines provided an admittance bridge covering the ranges required for aerial, H.F. cable and transmission line work, over the frequencies 1-50 Mc/s.—again a direct reading instrument, accurate, docile and simple to use. The technique shows promise of considerable extension; a prototype instrument already covers the frequency range up to 100 Mc/s., and is now in commercial development, while experiments indicate that useful results will be obtained up to at least 200 Mc/s. These bridges should prove invaluable for such work as the design of wide band F.M. aerials, and routine alignment of V.H.F. aerials and feeders. At the other end of the frequency spectrum, an audio-frequency bridge, based on similar principles, will make direct measurements of capacities as low as 0.0001 pF at the end of flexible leads, and of any one of three elements connected in mesh, ignoring the presence of the other two. This opens up new possibilities of *in situ* measurement, and greatly simplifies the determination of circuit strays.

The bridge illustrated is a new medium-wave model covering frequencies between 15 Kc/s. and 5 Mc/s. The basic circuit arrangement is shown in Fig. 1. It comprises two transformers, T_1 and T_2, a standard, Z_s, and the unknown, Z_u. T_1 can be regarded as a voltage transformer and T_2 as a current transformer.

Assuming ideal transformers with zero leakage inductance and zero resistance, and neglecting the inductance and resistance of the connexions, let the unknown winding W_u of T_2 have N_u turns and the standard winding W_s have N_s turns. At balance there is zero voltage across the detector winding W_D of T_2, and therefore the core fluxes set up by the currents in W_s and W_u must cancel. With zero leakage flux, the currents in the windings must be in inverse ratio to the turns, thus $\frac{I_s}{I_u} = \frac{N_u}{N_s}$ It also follows from the assumption of no leakage or core flux at balance that the voltages across W_s and W_u must be zero. That is to say, the terminals *a* and *b* are at the same potential as the neutral line. Since both Z_s and Z_u are fed on one side from a common potential point "C" on T_1, and since they are brought to the potential of neutral at balance, if the

* Wayne Kerr Laboratories.

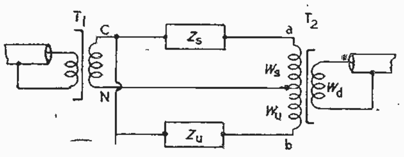


Fig. 1.

voltage supplied by T_1 is "E," then by Ohm's Law:—

Current through standard is $I_s = \frac{E}{Z_s}$

and Current through unknown is

$$I_u = \frac{E}{Z_u}$$

but since $\frac{I_s}{I_u} = \frac{N_u}{N_s}$, then $\frac{Z_u}{Z_s} = \frac{N_u}{N_s}$

$$\text{or } Z_u = Z_s\frac{N_u}{N_s}$$

that is to say, the unknown impedance is equal to the standard impedance multiplied by the turns ratio of W_u to W_s of the current transformer.

Consider now the stray capacities that prove so intractable in a classical bridge circuit at high frequencies. Some are shown in Fig. 2, others in Fig. 3. From Fig. 2 it is obvious that the shunt capacities C_1, C_2 and C_3 can cause no measurement error; C_1 because it merely produces a reactive voltage drop through the driving impedance, which is common to both unknown and standard, C_2 and C_3 because at balance the potential across them is nil.

C_u represents the capacity across the unknown terminals and its effect is cancelled by the trimming condenser C_r, on the standard side: this is adjusted by disconnecting the standard and balancing the bridge.

The effects of the stray capacities to earth (shown in Fig. 3) depend to some extent upon the manner in which the bridge is used. If the neutral terminal is earthed, the capacities to earth virtually disappear, since the capacity of the neutral to earth, C_n, is short circuited, and the capacity of the common point to earth, C_c, appears only as an additional shunt load across T_1, where it does no more than slightly reduce the volts available across the bridge. In addition, C_a and C_b are effectively short-circuited at balance, since a and b are brought to neutral potential, which is earth. If, on the other hand, one side of the unknown is at earth potential as, for example, in the measurement of an unbalanced impedance, earthing of the neutral has the effect of short-circuiting the unknown. In this case, therefore, the common terminal "C" is earthed and the result is as follows: C_c is short-circuited and C_n is in shunt with the source, but C_a is brought in shunt with the standard and C_b in shunt with the unknown impedance. Their respective effects must therefore be cancelled. From Fig. 2 it is seen that C_a merely augments C_r, while C_b augments C_u. If a preliminary balance is made by adjusting C_r before the standard and unknown are connected, errors due to these stray capacities are removed.

In the case of an unknown impedance, balanced with its centre point earthed, neither the neutral nor the common terminal may be earthed. One side of the unknown is connected to "C" and at balance, since there is zero voltage across W_u, the other side of the unknown is effectively connected to the neutral terminal, "N." The centre point of the secondary winding T_1 must therefore be brought to earth potential in order to avoid unbalancing the unknown. This is achieved by equalising C_c and C_n of Fig. 3 by adding a trimming condenser to whichever side shows the lowest capacity to earth; this is shown dotted in Fig. 3.

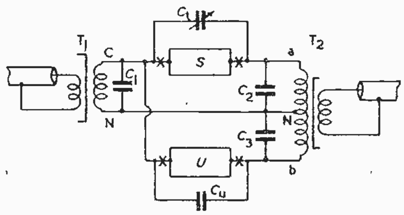


Fig. 2.

It is now necessary to examine the effect of leakage inductance in the transformers. Fig. 4 is a simplified diagram showing the leakage inductances as L_v, L_s and L_u. L_s and L_u, the leakage inductances of the standard and unknown windings of T_2, are shown returned to neutral as they would be in effect when the bridge is at balance. It is clear that the assumption that the current sides of the standard and unknown are at neutral potential at balance, is not

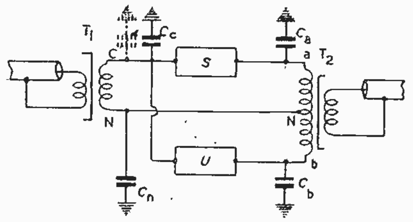


Fig. 3.

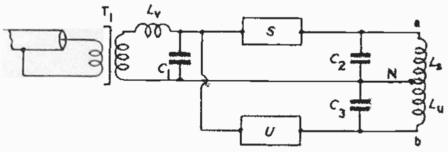


Fig. 4.

strictly true, owing to the reactive voltage drop on the leakage inductance. Neither is it true that C_2 and C_3 carry no current at balance, and so can be ignored. L_v can, however, be ignored as it merely causes a reactive voltage drop that is common to both standard and unknown. The effect of L_s and L_u is two-fold and can be explained as follows: Assume C_2 and C_3 removed, and the bridge balanced. Let E be the voltage between the common terminal and neutral, and I_s and I_u the currents through standard and unknown

respectively, then $I_s = \frac{E}{Z_s + j\omega L_s}$

$$\text{and } I_u = \frac{E}{Z_u + j\omega L_u}$$

Having removed the effect of the capacities, the whole of the current goes through the transformers, therefore:

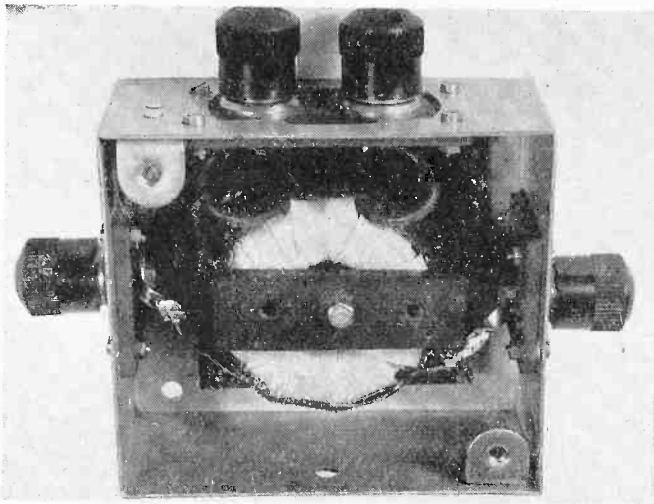
$$\frac{Z_u + j\omega L_u}{Z_s + j\omega L_s} = \frac{N_u}{N_s}$$

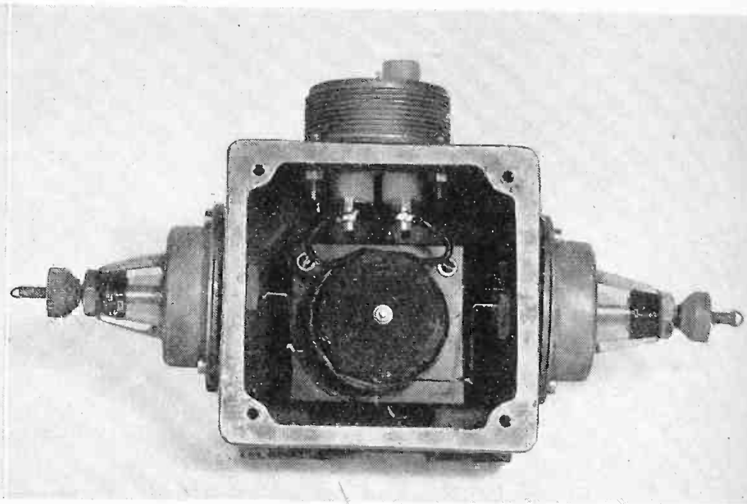
$$\text{and } Z_u = (Z_s + j\omega L_s)\frac{N_u}{N_s} - j\omega L_u$$

$$= Z_s\frac{N_u}{N_s} + j\omega\left(L_s\frac{N_u}{N_s} - L_u\right)$$

The second term on the R.H.S. represents a direct error in measurement, which can be removed only by making $L_sN_u = L_uN_s$. The effect of the shunt capacities C_2 and C_3 is to drain away a fraction of the current from the transformer windings so that the bridge no longer necessarily balances when $I_sN_s = I_uN_u$. Normally, however, the error due to this is of a second order since the reactance of the shunt capacity will, in practice, be several hundred times greater than the leakage reactance.

It should be noted that the series inductance in the circuit connexions can have an equally serious effect, especially on the unknown side where the impedance may be as low as 10 ohms. For this reason it is essential that leads carrying a "go" current should be positioned adjacent to leads carrying the corresponding "return" currents in order to minimise inductive loops.





Aerial Matching Unit for H.F. Reception

By T. E. BRAY, J. C. EATON, M.A., and J. W. WHITEHEAD, B.Sc.†

A description is given of the construction of a simple transformer for matching a balanced 100-ohm circuit to a balanced 600-ohm circuit, or vice versa. The unit is for reception purposes over the band 2 to 20 Mc/s.

IN this transformer a toroidal construction is adopted using a ring made $\frac{1}{8}$ in. mu-metal tape, the ring having respective internal and external diameters of 1 and $1\frac{1}{2}$ in. It is bound with a layer of oiled cloth tape.

The innermost winding is the high impedance side of the transformer and is wound with 21 turns of 30-strand Litz wire spaced evenly around the whole of the ring. The 100-ohm winding, spaced $\frac{1}{8}$ in. from the 600-ohm winding by oiled cloth tape, is made of 9 turns of 30-strand Litz wire equally distributed around the ring. The terminations of the windings are arranged to be diametrically opposite on the ring. The complete assembly is then housed in a steel box. The 600-ohm winding is connected to terminals on opposite sides of the box, while the 100-ohm winding is brought out to a pair of terminals, or a cable connexion, on one of the remaining sides. The illustrations of two such matching units which are shown in Figs. 1 (left) and 2 (right) demonstrate the construction clearly.

Electrical Characteristics

The variation with frequency of the resistive and reactive components of each winding are shown in the table below:

Frequency (Mc/s)	Resistive and Reactive Components of High Impedance Side (Ohms) (Low impedance side shunted with 100 ohms)	Resistive and Reactive Components of Low Impedance Side (Ohms) (High impedance side shunted with 600 ohms)
2	430+j125	75+j20
4	480+j 89	76+j19.5
6	520+j100	80+j18.5
8	530+j 40	81+j18.8
10	545+j 4	80+j20
12	550−j 12	80+j21
14	540−j 60	83+j21
16	570−j130	78+j24
18	560−j180	76+j25
20	540−j147	75+j30

Measurements are next given of the R.F. resistances and reactance of the 600- and 100-ohm carbon resistors employed to terminate the circuits during the above test.

Frequency (Mc/s)	100 Ohm Resstor		600 Ohm Resistor	
	Resistance (ohms)	Reactance (ohms)	Resistance (ohms)	Reactance (ohms)
3	110	0	660	− 23
6	112	2.7±1	645	− 34
9	110	5.0±1	630	− 78
12	107	9.6±2	605	−100
15	110	7.7±1	570	−117
18	115	7.5±1	540	−167

Consideration of these tables reveals the following approximate impedance transformation ratios:

(a) Looking into the high impedance side with the low impedance winding connected across the 100-ohm load.

Frequency (Mc/s)	Impedance Transformation Ratio
6	4.64
12	5.14
18	4.87

(b) Looking into the low impedance side with the high impedance winding shunted with the 600-ohm load.

Frequency (Mc/s)	Impedance Transformation Ratio
6	8.05
12	7.30
18	7.10

From these results it is clear that the transformer is quite suitable for matching 100- and 600-ohm balanced lines for reception purposes throughout the band 2 to 20 Mc/s.

† Central High School, Leeds

Future Possibilities of Navigational Radar

Mr. R. F. Hansford's Paper at the Institute of Navigation

SPEAKING at the Royal Geographical Society in November last on the development of ship-borne navigational radar, Mr. R. F. Hansford (late A.S.E.) suggested that navigational radar would develop along four main lines: (1) The existing P.P.I. is insufficiently bright to allow it to be used on the bridge in daylight, and some form of improved screen material is required.

Alternatively, the trace could be reproduced by television technique at a much higher speed of scan, giving a continuous bright picture which will eliminate the "flash and decay" effect. (2) The development of improved chart comparison units. An existing patent provides for the projection of the chart outline on the back surface of the P.P.I. tube by optical means, thus leaving the front surface unobstructed and causing no reduction in the intensity of the image.

If a dark trace tube or a television display were employed, it would be possible to project the tube trace on the chart with the corresponding advantage of an enlarged picture.

An outstanding problem with all forms of chart comparison display is that of moving the chart to keep pace with the vessel's movements. It would seem that, at any rate in larger ships, there may be a requirement to control the movement of the chart (or the P.P.I.) automatically from the ship's auto-log. An eventual development may be to have the position of the chart automatically controlled by the data from radio position-fixing system.

A special display for ship-handling.—A normal P.P.I. with its map-like presentation is from many points of view the ideal presentation for navigation. It is, however, arguable that the P.P.I. is not the best display for use in avoiding action or for general ship-handling. Under visual conditions most note is taken of the change in relative bearing of objects ahead; small changes in relative bearing are not always readily appreciable on a P.P.I. particularly at the crucial period when the echo is very near the centre of the P.P.I.

This difficulty might be lessened by providing on the bridge a special additional display showing a region ahead of the ship for, say, some 5,000 ft. with some form of presentation which increases the bearing accuracy at close ranges. This could be done either by using a considerably opened centre P.P.I. type display or by using a "B scope" (range-azimuth display), or by using a P.P.I. type with logarithmic range scale.

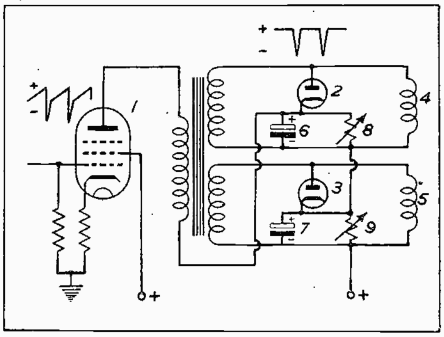
A very short range radar.—In pilotage many of the problems are short range range problems, as for example when it is desired to pass close to a buoy. Also, in pilotage problems the existing form of radar does not present its information in the most convenient form. It is conceivable that there is a need for auxiliary radar which could take over from the main radar at ranges of below one mile and which would present its information in a form to which a Watchkeeping Officer was more accustomed.

A method which is theoretically possible would make use of continuous radiation on a wavelength of a few millimetres. A beamwidth of a small fraction of a degree could then be achieved with an aerial which could scan in bearing and in elevation; a cathode-ray tube scanning in synchronism could then provide a bearing and elevation picture which would be in the same form as the view normally seen visually and capable of showing objects down to a distance of a few feet.

An Efficient Television Scanning Circuit

IT is known that the power amplifier in the line scan system of a television receiver circuit consumes a large fraction of the total power supplied by the high-tension system. Any means for increasing the efficiency of the scanning amplifiers, and in particular of the line scan amplifier, is therefore of interest, because good performance is then obtainable with reduced H.T. current consumption. The following circuit provides an improved line scan circuit whose improved efficiency is due to the fact that energy that is normally lost in the deflection coil circuit is regained and supplied, as a boost to the H.T. to the anode circuit of the deflection amplifier.

The power amplifier *1* has its grid and screen operating potentials supplied in a conventional manner, while the grid is driven by the usual sawtooth voltage at line scan frequency with negative-going pulses between the sawtooth waveforms.



Deflecting currents of sawtooth form appear in the line deflecting coils *4* and *5*, while the difference of potential across the coils consists of a steady positive voltage with negative-going gaps as indicated in the diagram. The damper diodes *2* and *3* operate in a conventional manner to prevent the flow of oscillatory currents at the self-resonant frequency of the deflecting coil circuit, while the variable series resistors *8* and *9* are deflection linearity controls.

In operation, the damper diode currents charge the storage condensers *6* and *7* which then discharge slightly during the scanning period. There are thus developed rectified voltages across the condensers *6* and *7* which are added to the conventional H.T. supply in order to boost it before it is applied to the power amplifier anode circuit. In practice, a boost of the order of 30 per cent. is readily obtained, and in a circuit set-up according to the diagram a line scan supply voltage of 485 volts was obtained from a receiver H.T. supply of only 385 volts.

Where deflection coils *4* and *5* are in series, one diode only is needed.

—Communication from R.C.A.

NOTES FROM THE INDUSTRY

20th Century Electronics

Mr. E. E. Shelton has recently joined Mr. Gilbert A. R. Tomes as a partner in 20th Century Electronics, whose activities are chiefly the development and manufacture of Geiger-Muller Counter Tubes, Photo-electric Cells and specialised vacuum devices. The G.M. Tubes are at present marketed by Messrs. Alltools, Ltd., Brentford, Middlesex.

20th Century Electronics have purchased the assets of Dr. F. J. G. van den Bosch, formerly trading as Vacuum Physical Laboratories, and are now operating from Dunbar Works, Dunbar Street, West Norwood, S.E.27. Telephone No. Gipsy Hill 3351.

Soldering Tags and Rivets

Many small manufacturers and experimental laboratories require soldering tags, eyelets, or rivets in quantities of a few hundred for assembly work, but feel that orders for such quantities would hardly be welcomed by bulk manufacturers, such as the Tucker Eyelet Co.

We are informed that Messrs. W. J. Cons and Co., of 281 Green Lanes, N.4, who specialise in punching and eyeletting machines, are able to supply rivets and eyelets in quantities from a gross upwards.

The following Tucker tags are in stock at the time of printing:

W. 3 = Tucker No. G.709 single-ended tag for riveting.
W. 2 = Tucker No. G.602 single-ended short and long.
W.21a = G.866a double-ended U-shaped tag.
W.22 = G.603 double-ended flat tag.
W.43 = G.856.
W.50 = S.76 double-ended flat tag with square rivet and slotted holes.
W.51 = G.860 double-ended flat tag with larger rivet and slotted holes.
W.52 = S.88 double-ended soldering tag. No rivet.
W.44 = G.717 one long, one short end riveting tag.
W.46 = G.363 single soldering tags, 2 and 6 B.A.
W.45 = G.410 single soldering tag, 4 B.A.

Eyelets for riveting:

Card No.157 = G.601 7/32 in. and 5/32 in. eyelets. Various lengths.
Card No. 59 = G.594 ¼ in. and 7/32 in. eyelets. Various lengths.
Card No. 8 = G.169 small brass eyelets.

All these are 2s. per gross plus postage and C.O.D. charges, or cash with order.

Handsets to set tags are available in a wide range at approximately 9s. 6d. per set plus C.O.D. charges.

Cinema-Television Ltd.—Exhibition

From January 20 to 31 a trade exhibition of "Cintel" Electronic Instruments is to be held at Brettenham House, Lancaster Place, London, W.C.2. (9.30 a.m. to 5 p.m. daily except Sunday). Admission is by ticket, obtainable from Cinema-Television, Ltd., Worsley Bridge Road, Lower Sydenham, London, S.E.26.

School Broadcasting

In a report issued by the School Broadcasting Council for the United Kingdom, 55 Portland Place, London, W.1, it is stated that, with the co-operation of the Education Authority, a school at Tottenham has been equipped with a demonstration installation to show the best current practice. This installation may, by arrangement with the Secretary of the School Broadcasting Council, be visited by members of Education Committees, Directors of Education and others concerned.

Radio Noise

An Important Survey of Information

The study of noise level and the limitation which it imposes on signal reception has received far less attention that the study of radio wave propagation, and lack of knowledge of the subject is retarding progress in many communication problems. The publication of a survey of the state of knowledge on the subject of radio noise is consequently of some importance. It is "Radio Research Special Report No. 15—a Survey of existing information and data on Radio Noise over the Frequency Range 1-30 Mc/s."*

The report contains a survey of all existing knowledge on the subject of radio noise. It has been prepared in the Radio Division of the National Physical Laboratory, D.S.I.R., where some 180 published papers on the subject were examined and also data and measurements made available by certain commercial and government organisations, operating radio services in Great Britain.

It deals also with the measurement of the strength of noise and its direction of arrival, and it is in these fields that active research is now in progress with a view both to obtaining a better understanding of the origin and nature of radio noise of all types, and also to developing techniques of limiting or mitigating the effects of these disturbances to radio communication. Such investigations are now being started in various parts of the world, and this report provides a good foundation as a comprehensive presentation of existing knowledge.

* Published for the Department of Scientific and Industrial Research by H.M. Stationery Office, Kingsway, London, W.C.2. (price 3/-, post free 3/4)

Publications Received

Gardners Radio, Ltd., Somerford, Christchurch, Hants.—Leaflet No. LMT4 on "Somerford" Mains Transformers, the standard range of which contains 59 different types.

Goodmans Industies, Ltd., Lancelot Road, Wembley, Middx.—Public address Cabinet Loudspeaker type AL/5 incorporating the Goodmans 12 in. PM type T2/1205/15 are covered in their latest pamphlet which also deals with their heavy duty line transformer type H5.

Holliday and Hemerdinger, Ltd., 74-78 Hardman Street, Manchester 3.—Price list of available radio components.

Steatite and Porcelain Products, Ltd., Stourport, Worcs.—Four leaflets dealing with coil formers and inductors (No. 29), Stand-off and Aerial Insulators (No. 30), Metallised Brushes (No. 31) and Insulating Beads (No. 32).

London, Midland and Scottish Railway.—Publication No. E.R.O.53574 is a 24 page illustrated booklet on the Scientific Research Department of the L.M.S. covering the activities of the Engineering, Metallurgical, Paint, Physics, Textile and Chemical Sections.

Mullard Technical Report No. 2/1947 on the EL37 25 watt output pentode. This 38 page report gives comprehensive figures and curves on the valve as a single pentode, push-pull pentode or push-pull triode. The issue is strictly limited and has already been allocated; it is not available for general distribution.

British Standard Specification

Electronic-Valve Bases, Caps and Holders

Under this title the British Standards Institution have issued B.S. 448: 1947 (net price 7s. 6d.). It forms an extension of previous issues to include other types of valve and cathode ray tube bases introduced subsequently.

While the 1936 edition of this British Standard dealt purely with the dimensional requirements, in this edition a clause dealing with effective electrical connexion has been added to the paragraphs relating to holders. The connexions between valve base-pins and internal electrodes are no longer covered in the Standard.

Bartered Bits

A Greek firm of Athens wishes to establish a connexion with a Belgian exporter of electrical and electronic material in exchange for Greek wines (Samos).

Write to: United Radio Laboratories, Canning's Square Building George 6, Athens.—Advt. in *La Radio. Revue*, Aug. '47.

JANUARY MEETINGS

Institution of Electrical Engineers

Radio Section

Date: January 14. Time: 5.30 p.m.
Lecture: "Reference-Crystal-Controlled V.H.F. Equipments."
By: D. M. Heller and L. C. Stenning.
Date: January 20. Time: 5.30 p.m.
Discussion: "To what extent does Distortion really matter in the Transmission of Speech and Music?"
Opened by: P. P. Eckersley.

Informal meeting

Date: January 26. Time: 5.30 p.m.
Discussion: "The British Patent System and Procedure."
Opened by: C. S. Parsons, B.Sc.

Measurements Section

Date: January 30. Time: 5.30 p.m.
Discussion: "Principles of Instrument Design."
Opened by: D. C. Gall *et al.*
Note: This is a joint meeting with the London and Home Counties Branch of the Institute of Physics.
The Secretary: I.E.E., Savoy Place, W.C.2.

Sheffield Sub-Centre

Date: January 28. Time: 6.15 p.m.
Held at: The Royal Victoria Station Hotel, Sheffield.
Lecture: "Developments on Magnetic and Acoustic Mines at the Admiralty Mining Establishment."
By: A. J. Baggott and C. H. Fawcett.
Hon. Secretary: E. W. Connon, 13 Marsh House Road, Sheffield 11.

North-Western Centre

Date: January 21. Time: 6.30 p.m.
Held at: The Engineers Club, Albert Square, Manchester.
Lecture: "Triodes for very Short Waves."
By: J. Bell, B.Sc. *et al.*
Asst. Secretary: A. L. Green, 244 Brantingham Road, Chorlton-cum-Hardy, Manchester 21.

North-East Scotland Sub-Centre

Date: January 7. Time: 7.30 p.m.
Held at: The Caledonian Hotel, Aberdeen.
Lecture: "The Design of a High Fidelity Disk Recording Equipment."
By: H. Davies, M.Eng.
Date: January 8. Time: 7 p.m.
Held at: The Royal Hotel, Union Street, Dundee.
Lecture: As above.
Hon. Secretary: P. Philip, c/o Electricity Supply Dept., Dudhope Crescent Road, Dundee.

Cambridge and District Group

Date: January 13. Time: 6 p.m.
Held at: The Cambridgeshire Technical College (Room 301).
Radio Section Chairman's Address.
By: C. E. Strong, B.A.I., M.I.E.E.
Hon. Secretary: J. E. Curran, University Engineering Laboratory, Trumpington Street, Cambridge.

Institute of Physics

Scottish Branch

Date: January 13. Time: 7 p.m.
Held at: Natural Philosophy Department, The University, Glasgow.
Lecture: "The X-ray Study of Coal Structure."
By: Professor H. L. Riley.
Secretary: J. M. A. Lenihan, The University, Glasgow, W.2.

Manchester and District Branch

Date: January 16. Time: 7 p.m.
Held at: The New Physics Theatre, University of Manchester.
Lecture: "The Cloud Chamber."
By: J. C. Wilson, M.A., Ph.D., F.Inst.P.
Note: This is a joint meeting with the Electronics Group.
Secretary: Dr. F. A. Vick, Physics Department, The University, Manchester 13.

South Wales Branch

Date: January 21. Time:
Held at: The Physics Department, Univesity College, Cardiff.
Lecture: "Colour Vision."
By: Dr. W. D. Wright.
Secretary: Dr. T. V. I. Starkie, Monmouth Mining and Technical College, Crumlin, Mon.

London and Home Counties Branch

Date: January 30. Time: 5.30 p.m.
Joint meeting with the Measurements Section of the Institution of Electrical Engineers (see col. 1).

Institution of Post Office Electrical Engineers

All meetings will be held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Date: January 6. Time: 5 p.m.
Lecture: "The Location of Faults in Lines and Cables."
By: Capt. A. C. Timms, B.Sc., M.I.E.E.
Local Secretary: W. H. Fox, Engineer-in-Chief's Office (T.P. Branch) Alder House, E.C.1.

South-East London Technical Institute

Electrical Engineering Department

A course of ten weekly lectures will commence on Wednesday, February 18, 1948, from 7 to 9 p.m. entitled "X-ray Crystallography with special reference to Metallography." Further details may be obtained from The Registrar, L.C.C. South-East London Technical Institute, Lewisham Way, London, S.E.4.

British Kinematograph Society

Newcastle-on-Tyne Section

Date: January 6. Time: 10.30 a.m.
Held at: Neville Hall, Neville Street, Newcastle.
Lecture: "The Cathode Ray Tube."
By: G. Parr, M.I.E.E.
Hon. Secretary: E. Turner, 30 Ettrick Grove, Sunderland, Co. Durham.

Radio Society of Great Britain

All meetings are held at the Institution of Electrical Engineers, Savoy Place, London, W.C.2.
Date: January 9. Time: 6.30 p.m.
Lecture: "The Design and Construction of Amateur Transmitters."
By: J. N. Walker.
General Secretary, New Ruskin House, Little Russell Street, London, W.C.1.

British Sound Recording Association

All meetings are held at the Royal Society of Arts, John Adam Street, London, W.C.2.
Date: January 23. Time: 7 p.m.
Lecture: "The Significance of the Amplifier in High Fidelity Recording and Reproduction."
By: H. J. Leak.
Hon. Secretary: R. W. Lowden, Napoleon Avenue, Farnborough, Hants.

The Television Society

Ordinary Meeting

At the Institution of Electrical Engineers, Savoy Place, W.C.2.
Date: January 28. Time: 5.30 p.m.
Lecture: "Large Screen Home Television."
By: E. G. O. Anderson (J. L. Baird, Ltd.)
Lecture Secretary: T. M. C. Lance, 35 Albemarle Road, Beckenham, Kent.

Constructors' Group

Date: January 9. Time: 7 p.m.
Held at: The E.L.M.A. Lecture Theatre, 2 Savoy Place.
Lecture: "The Pye Television Receiver."
By: D. Swaine (Pye Radio Ltd.)
Group Secretary: A. E. Sarson, 22 Union Road, Bromley, Kent.

Programme Group

The inaugural meeting of the Programme Group will be held at the Gaumont-British Theatre, Wardour Street, W.1, on January 16 at 6 p.m., to which ladies are specially invited.
The chair will be taken by Sir Robert Renwick, Bart., President of the Society.

Tickets of invitation can be obtained from the Lecture Secretary at the address given above.

BOOK

Radio Engineering

E. K. Sandeman, Ph.D., M.I.E.E., Chapman & Hall. XXIV and 775 pages. Price 45s.

A demerit of the title of this book is its identity to that of a universally known American publication and that it gives little indication of the contents. A title more illustrative of the field covered would be "Broadcast Engineering," for the greater part of it is devoted to an analysis of problems concerned with broadcast transmitters. Its 775 pages represent an enormous expenditure of effort on the part of the author, who freely acknowledges the assistance he has received from many members of the B.B.C. technical staff.

The author states that he has tried to produce a book suitable for beginner and professional engineer alike. Beginners may well quail before the mass of information and are certain to find the latter half of the book heavy going. Professional broadcast engineers will be irritated by the first 300 pages, most of which will be of little use to them. The author would have been well advised to divide his work into two separate and distinct books. Neither price nor style are likely to appeal to the beginner.

Turning to a detailed examination of the book, there are 16 chapters in this first volume, a very complete list of contents, and a 22 page index covering this and the Volume 2 yet to be published. The first chapter briefly describes the technical problems associated with broadcasting, and the second is concerned with electrical units, definitions, conversion tables and the like. Chapters 3 and 4 deal with elementary trigonometry and problems involving D.C. voltages and currents. Relations between A.C. voltages and currents are the subject of chapter 5, and here the Reciprocity and Thévenin's Theorems precede Kirchhoff's laws. Chapter 6 covers resonant circuits from the transmitter engineer's angle. Power in A.C. circuits is the title of the next chapter which includes a discussion on a wide range of topics—such as decibel notation, programme-to-noise ratio, reflection and transition loss, KVA to KW ratio in transmitters—of general interest to the broadcast engineer. Harmonic Analysis and Distortion are reviewed in chapter 8, which is followed by a generally disappointing chapter on Valves. So little has been written on transmitting valves that a discussion on these essential items should have occupied more than a fifth of a comparatively short chapter. From this point onwards (page 300) the book assumes its real value to the broadcast engineer. It begins with a chapter on amplifiers; Class A, B and C. operation is examined in considerable detail and practical examples are used to illustrate methods of calculating efficiency and estimating peak currents. Neutralisation and the inverted amplifiers are also included. Chapters 11 and 12 on Oscillators and Drive Equipment respectively call for little comment; the section on Drive Equipment will interest more particularly those who are not members of the B.B.C. staff and the same remark applies to chapter 15 on Operation and Maintenance of Transmitters. Modulators and Modulation, and Transmitter Types are the subject of chapters 13 and 14, in which much useful information will be found. The last chapter is specifically directed to the aerial maintenance engineer at large transmitting stations, and it covers very adequately feeders, aerial couplling circuits and aerials themselves, including the purely mechanical problems of ice, windage, etc.

There are a larger number of misprints—not all of which can be ascribed to the printer—than should occur in a book of this standard, and the word "evidently" is employed far too often and in a most unusual sense. The method of presentation is not always lucid, and particularly is this so with the description of the Chireix system of modulation in chapter 14. Some strange and illogical sequences are also to be found. For example: work, energy, power, mass, etc., are defined at a later stage than permeability, inductance and skin effect; the principles of modulation occur at the end of a chapter on modulation. It is odd to find a section on how to proceed after a transmitter flashover has occurred in a chapter devoted to electrical units.

The book will be of considerable interest and value to all those engaged on the design and/or maintenance of broadcast transmitters, and the full list of contents will be of great help when only particular items are required. To beginners and operators of broadcast transmission equipment, the book will be less valuable.

K. R. STURLEY

Second Year Radio Technology

W. H. Date. 214 pp. 154 figs. (Longmans Green & Co. 7s. 6d. net).

This book has been written particularly for second-year radio students and therefore omits the preliminary electrical and magnetic theory. It is suitable for C. & G. Grade I examination and the National Diploma courses,

REVIEWS

and reproduces test questions taken from the C. & G. papers.

The chapter headings are: Capacitance, Inductance, Resonant Circuits, Thermionic Valves (diodes, triodes, etc.) and their circuits, D.F., superhets., and finally R.F. instruments and measurements.

Mr. Date's reputation as a teacher at the Polytechnic is well known, and this book will no doubt be acceptable as a class-book by many teachers engaged on the same work.

The A.B.C. of Electronics

E. B. Watton, 133 pp. 118 figs. (Percival Marshall & Co. 7s, 6d. net).

The writing of simple introductory books is always a difficult task, however well the writer is equipped to do it.

He is faced with the alternative of being really simple and not introducing any technical term without explaining it beforehand—which means that he never gets to the real subject—or slurring over the technical preliminaries and going on to the hard parts in the hope that the reader will follow him.

The author of this book has chosen the second course, after excusing himself in the preface for being brief in his descriptions, and has pursued it very well on the whole. The general criticism that might be levelled at the book is that it attemps to cover too much. After all, an A.B.C. need not claim to cover more than the principles of electronics and its applications, with one or two typical examples, but in this book there are magnetrons, disk seal tubes, infra-red viewers, Eniacs, and talking clocks. It would have been better to have called it "What electronics can do."

In the introduction to television, the author says: "In an ordinary broadcast receiver, sound waves impinging upon a microphone diaphragm causes (*sic*) low frequency oscillations in the associated circuits which modify the carrier generated by the oscillator. The resulting modulated wave, when received, suitably amplified and rectified or detected, causes similar low frequency oscillations in the receiver circuit, which when applied to the loudspeaker diaphragm, reproduce the original speech frequencies," and then adds: "Sorry to be so elementary but we must get the principles firmly fixed." The reviewer is still wondering whether this is ironical or not.

There is no doubt that the subject is covered very widely with a wealth of illustrations—some of them excellent. The book is written in an easy style, and to a reader who knows the vocabulary, it will be interesting and profitable reading.

G. PARR

A Catalogue of Scientific Apparatus

THERE is something about a catalogue, particularly a fat one. It can be picked up and put down at random, imaginary shopping lists can be made *ad lib.* from it, it revives memories in parts, and above all, it gives ideas. As a source of entertainment and relaxation it can have few equals in the book world.

The American Army authorities knew this when they ordered quantities of Sears Roebuck catalogues to be sent from America to the units in Europe—it had the universal appeal.

The attraction of a scientific catalogue to scientific people is no less. Though they may never have used half the apparatus listed, it is good to look at it. No one can turn the pages and not find something which stimulates a train of thought.

As reading matter, a scientific catalogue is no mere list of component pieces and laboratory appliances—it gives notes, explanations, and sometimes enough material to warrant being classified as a text-book.

The catalogue which has brought out this eulogy on its class is the Griffin and Tatlock Catalogue of Scientific Apparatus, first post-war edition. Here is all the laboratory apparatus of student days, as sound and as fundamental as ever, but with modern companions. The Resistance Coil "in brass case with ebonite top" is now close to Strain Gauges (from 3s.).

Five hundred odd pages list all the equipment (and some more) that modern teaching may be expected to require. The index occupies 12 pages of close print and itself provides material for speculation that can only be satisfied by reference to the items.

What is Roget's Jumping Spiral? Did he play with it in the intervals of writing his Thesaurus? Who was Knipp, and what was the Tube that he designed? How many dead and gone physicists have left their names only in the index of Griffin's Catalogue!

Modern physics is not neglected and there are 12 pages given to Atomic Physics. The salts of Uranium (but not the metal) are listed in the Chemicals. Electronics, oddly enough, appears as an adjunct to atomic physics, and one looks for Valves, radio, in vain!

It is unfair, however, to point out any shortcomings in such a production when so much that is new and well-made is available, and at marked prices.

This ends on a sad note: the catalogue is, alas! not for sale. But if you are a sufficiently Important Scientist you may be privileged to have one sent to you.

G.P.

ABSTRACTS OF ELECTRONIC LITERATURE

THERMIONIC DEVICES

Note on the Ionisation Time of an Argon-filled Relay

(*E. W. Webster*)

Details are given of some experiments in which the voltage collapse across an Osram GT1C argon-filled relay when triggered by a steep-fronted rectangular impulse voltage on the grid, was recorded on a high-speed cathode ray oscillograph. Curves showing the variation of ionisation time with grid over voltages up to 50 V and with anode voltages up to 240 V are given, and typical oscillograms showing the marked effect of the amplitude of the grid impulses are reproduced. Ionisation times ranging from 0.16 to 2.2 μsec. were measured. A brief discussion of the oscillograms with reference to previous studies is included.

—*Jour. Sci. Inst.*, November, 1947, p. 299.

The Diode as an A.C. Voltmeter

(*C. S. Bull*)

The sources of error in existing methods of using the diode as an A.C. voltmeter are discussed. It is shown that, using a calibrated D.C. voltmeter and a sensitive current meter the calibration curve can be expressed in the form $y = I_o(BV_o)$, where B is determined experimentally and V_o is the peak A.C. voltage. This curve can be used to measure voltage in the range up to 0.4 V and in a greater range without accurate knowledge of the sensitivity of the meter, and the accuracy can be checked.

Using a knowledge of the sensitivity of the current meter as well, the power w absorbed from the A.C. source can be calculated from $w = i_E V_o I_1(BV_o)$, where i_E is the current through the valve when $V_o = 0$.

The method has been found to give reliable results at frequencies up to 100×10^6 c/s.

—*Jour. Sci. Inst.*, October, 1947, p. 254.

MEASUREMENT

A Remarkable Property of Technical Solid Dielectrics

(*M. Gevers and F. K. du Pre*)

Measurements on solid dielectrics carried out in the Philips laboratory to determine the loss angle and the temperature coefficient of the dielectric constants have revealed a relationship between these two quantities. This relationship is that, apart from a few exceptions, the substances which have a high temperature coefficient have at the same time a large loss angle, and the ratio between the two quantities is practically constant. Numerical data on these properties is given, and expressions are derived for the loss angle and the temperature coefficient; it is shown that the calculated values of this proportion correspond with those obtained experimentally.

—*Philips Tech. Rev.*, No. 3, 1947, p. 91.*

New Meters for Germicidal Energy

(*A. H. Taylor and H. Haynes*)

Exposures to ultra-violet energy necessary to destroy many types of micro-organisms are being studied by investigators at the G.E. Company, U.S.A. Three new germicidal energy meters have been developed recently; their functions are to determine (a) the reflexion of germicidal energy by walls; (b) the intensity of energy at various points in the room; and (c) the total output from an ultra-violet lamp. The three meters are described briefly, and mention is made of their range of sensitivity.

—*Gen. Elec. Rev.*, October, 1947, p. 27.*

Recorder and Timer for Short Intervals

(*W. H. Bliss*)

Designed to meet the needs of nucleonic research, this interval timer measures and records intervals up to 16 microseconds with an accuracy of 0.25 microsecond. Intervals to be measured may occur at random and be widely separated.

—*Electronics*, November, 1947, p. 126.

Measurement of Electron Microscopy

(*E. F. Fullam*)

The accuracy of measurements made with the electron microscope is dependent on the accuracy of magnification calibration, for which a number of methods are available. Measurements are made by methods very similar to those employed with the optical microscope except that electron micrographs are used instead of employing the microscope directly. An advantage of the electron microscope for measurement purposes lies in the high-image resolution and contrast for the measurement of structures down to colloidal and molecular dimensions. An added advantage of the electron microscope is the great depth of field, permitting stereoscopic pictures to be made.

—*Gen. Elec. Rev.*, October, 1947, p.18.*

* Abstracts supplied by the courtesy of Metropolitan-Vickers Electrical Co. Ltd. Trafford Park, Manchester

INDUSTRY

The One Million-volt Accelerating Equipment of the Cavendish Laboratory Cambridge

(*W. E. Burcham*)

This apparatus provides a magnetically resolved beam of protons or deuterons of 70 = 100μA. The maximum design voltage is 1,250 KV but this value cannot be used owing to the proximity of the laboratory walls. With a pressure in the accelerating tube of less than 0.0003 mm. Hg steady operation at 950 KV is achieved. About 3 cc. of hydrogen are consumed per minute. A short description of the applications of the equipment is given, including work on transmutation. The H.T. generator is of Philips construction.

—*Nature*, September 6, 1947, p. 316.*

A 70 MeV Synchrotron

(*F. R. Elder, A. M. Gurewitsch, R. V. Langmuir and H. C. Pollock*)

A synchrotron for the production of 70 MeV X-rays has been built and tested. The magnet which weighs 8 tons, is similar to that of a Betatron; the pole pieces are of laminar construction, thoroughly insulated against eddy current loss. Approximately 35,000 ampere turns r.m.s. are needed for 70 MeV operation. The apparent power is furnished at 22,900 volts r.m.s. from a capacitor bank through a high voltage cable to the coils which are in series. The orbit location is shown to be of importance only while the magnetic field is low; the orbit has been shifted over a wide region with little change on the X-rays output. The power circuit and operation of the apparatus are described.

—*J. App. Phys.*, September, 1947, p. 810.*

Electronic Computor for X-Ray Crystal Structure

(*R. Bepinsky*)

An electronic synthesiser is described for determination of atomic positions in crystals. It sums the two-dimensional Fourier series representing planar, centro-symmetric projections of electron densities in a crystal unit cell; the projection is presented by a television scan on the screen of a cathode ray oscilloscope. The specific advantage of the device is the immediate observability of effects on the projection of alterations in signs of one or any number of Fourier coefficients.

—*J. App. Phys.*, July, 1947, p. 601.*

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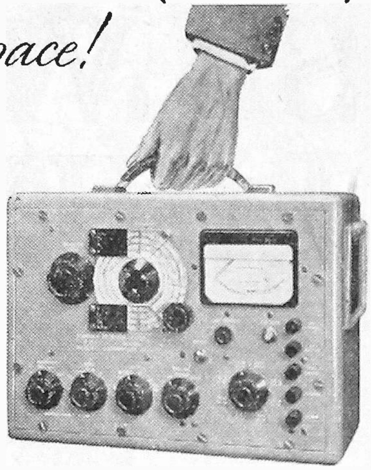

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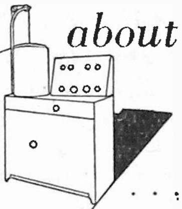

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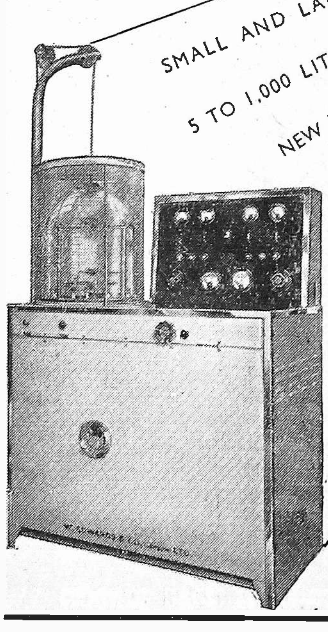

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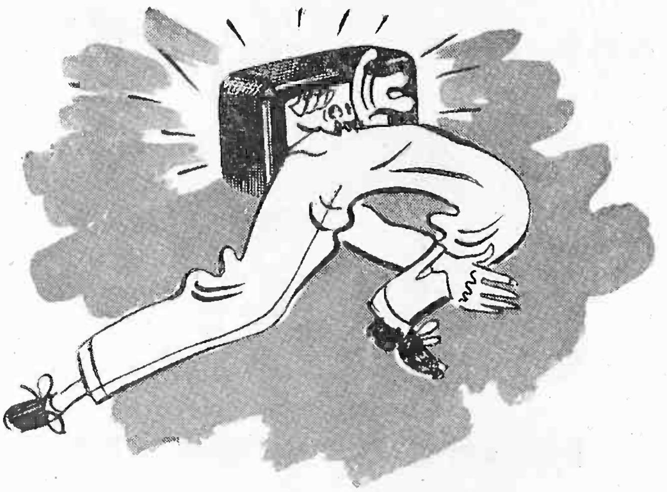

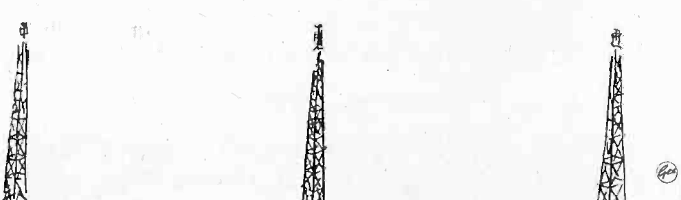

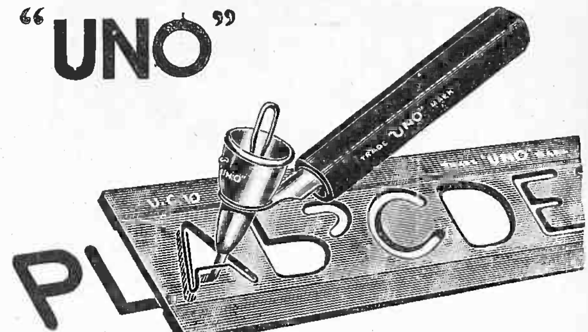

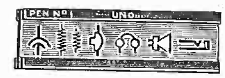

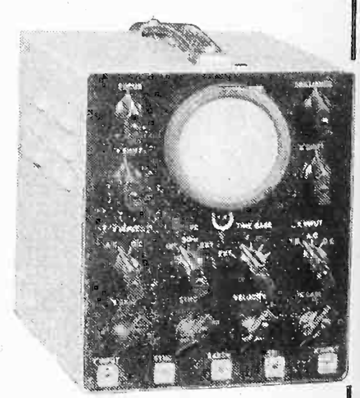

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