WIRELESS ENGINEER

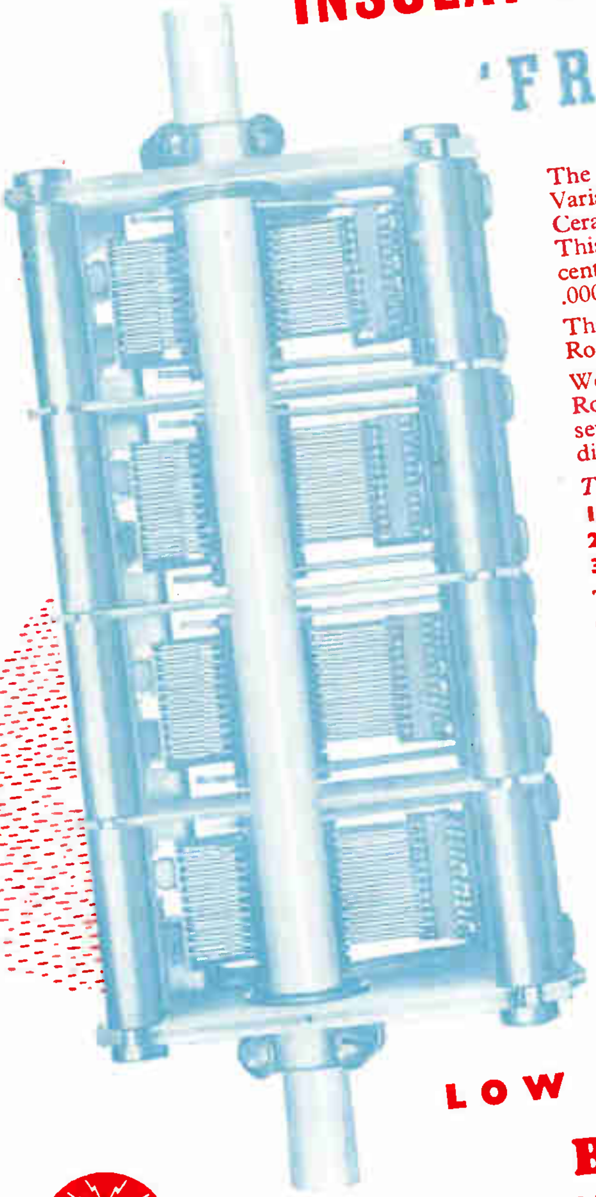
THE JOURNAL OF RADIO RESEARCH & PROGRESS

SEPTEMBER 1952

VOL. 29 No. 348 THREE SHILLINGS AND SIXPENCE

FOR HIGH-FREQUENCY INSULATION—specify

'FREQUELEX'



The illustration shows a Four Gang Radio Variable Condenser using our **"FREQUELEX"** Ceramic Rod for the Centre Rotating Spindle. This Rod is 7½″ long × .437″ diameter, centreless ground to within plus or minus .0005″. Maximum camber allowance of .002″.

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

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

The Principal Materials Are :—

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

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

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

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

Condenser manufactured by Messrs. WINGROVE & ROGERS LTD.

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TRADE MARK

'VARIAC' voltage regulating transformers

Reg'd Trade Mark

With a 'VARIAC' voltages are instantly and minutely adjustable from 0-Line Voltage, or in some cases up to 17% above line voltage. Type 50-B 'VARIAC,' as illustrated left, is often operated in a 3-gang assembly on 3-phase work to control 21Kva.

Type 200 C.U.H. 'VARIAC'

Type 100-R 'VARIAC'

SERIES 50 'VARIAC' TRANSFORMERS.

SPECIFICATIONS

Type	Load Rating	Input Voltage	Current		Output Voltage	No-Load Loss	Net Price £ s. d.*
			Rated.	Maximum			
50-A	5 kva.	115 v.	40 a.	45 a.	0-135 v.	65 watts	44 18 6
50-B	7 kva.	230/115 v.	20 a.	31 a.	0-270 v.	90 watts	44 18 6

* All 'VARIAC' prices plus 20% as from 23rd Feb. 1952

Write for catalogue V549 which gives full details of 'VARIAC' transformers and suggestions for use.

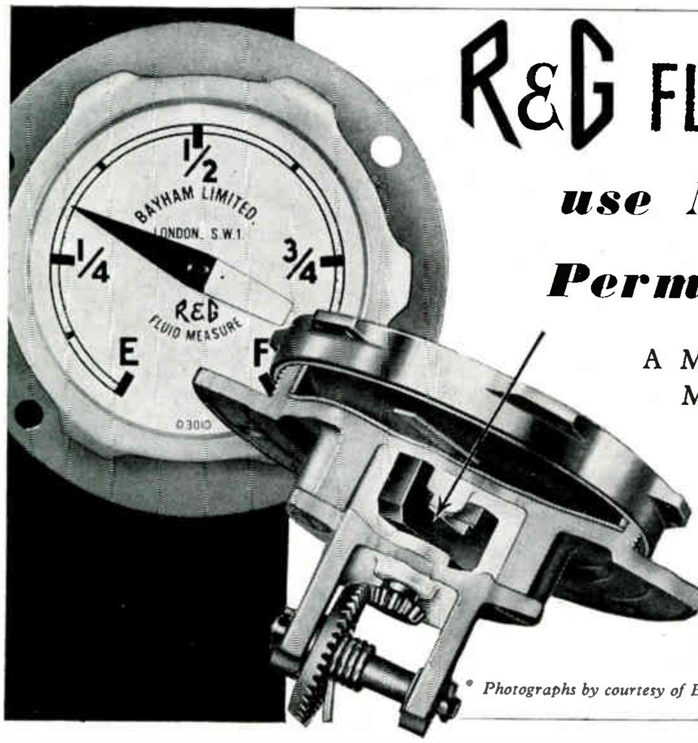
PROMPT DELIVERY OF "VARIAC" TRANSFORMERS

CLAUDE LYONS LIMITED

ELECTRICAL AND RADIO LABORATORY APPARATUS, Etc.

180 Tottenham Court Road, London, W.1 ; and 76 Oldhall Street, Liverpool 3, Lancs.


MUIRHEAD
technique
A JOURNAL OF INSTRUMENT ENGINEERING
VOLUME 6 · NUMBER 2
APRIL 1952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From the Channel Islands to the Shetlands, from the Thames to the West Coast of Ireland . . . 40 lighthouses and lightships around the coasts of Great Britain and Ireland are to be equipped with Marconi Marine Beacons by the Lighthouse Authorities. These M.F. Beacons will be fully duplicated with changeover switching, indicating and alarm facilities; in addition specially selected stations in the vicinity of the main ports will provide 'request' transmissions.

MARCONI marine beacons

MARCONI'S WIRELESS TELEGRAPH COMPANY LTD · CHELMSFORD · ESSEX

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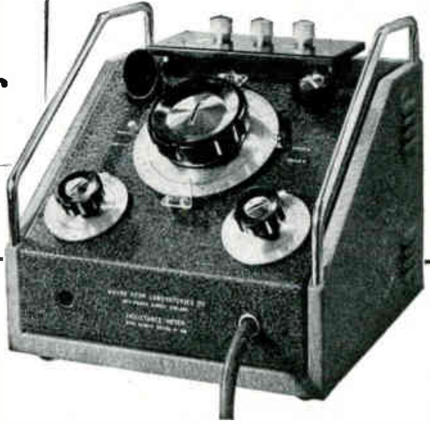

INDUCTANCE METER

Designed to provide simple and direct reading measurement of inductance values between 0.05 microhenry and 100 millihenrys. A stable variable-frequency oscillator is used to resonate the unknown inductance with a fixed standard capacitor. Provision is made for the measurement of Q at resonance frequency. Calibration and scale reading accuracy are sufficient to provide direct readings of inductance values within 2 per cent. above one microhenry. Relative measurement can be made with greater accuracy. The instrument is very compact, measuring only 7¼" high, 7¼" wide and 7⅝" deep at base.

THE WAYNE KERR LABORATORIES LTD. NEW MALDEN SURREY : MALDEN 2202

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co-axial plugs and sockets

These connectors enable identical cables to be joined together, or flexible cables to be joined to their lead-sheathed counterparts. They are fully waterproofed and suitable for use up to 3,000 Mc/s. The flange may be fitted to either half for passing cables through panels.

Illustrated is the 53/29M Plug and 53S/29M socket, for use with PT29M cable; also the 53C panel-mounting socket for terminating cable runs and the 53S protective cap for excluding dust and moisture.

All types are readily available in various sizes and combinations. Write for publication T/1

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TELCON RF cables

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All enquiries to: Telcon Works, Greenwich, S.E.10.
Tel: GREenwich 3291

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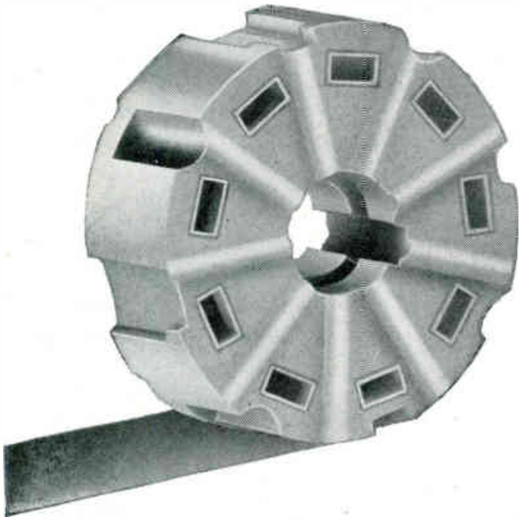

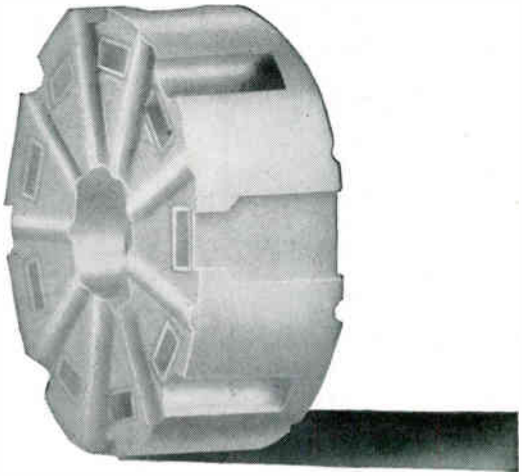

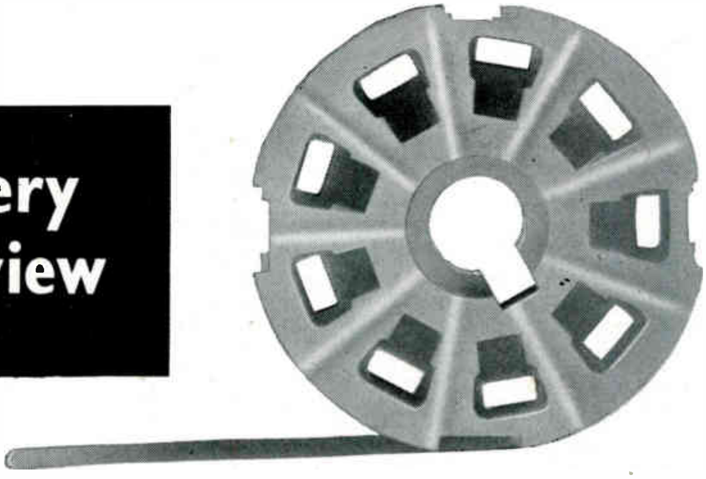

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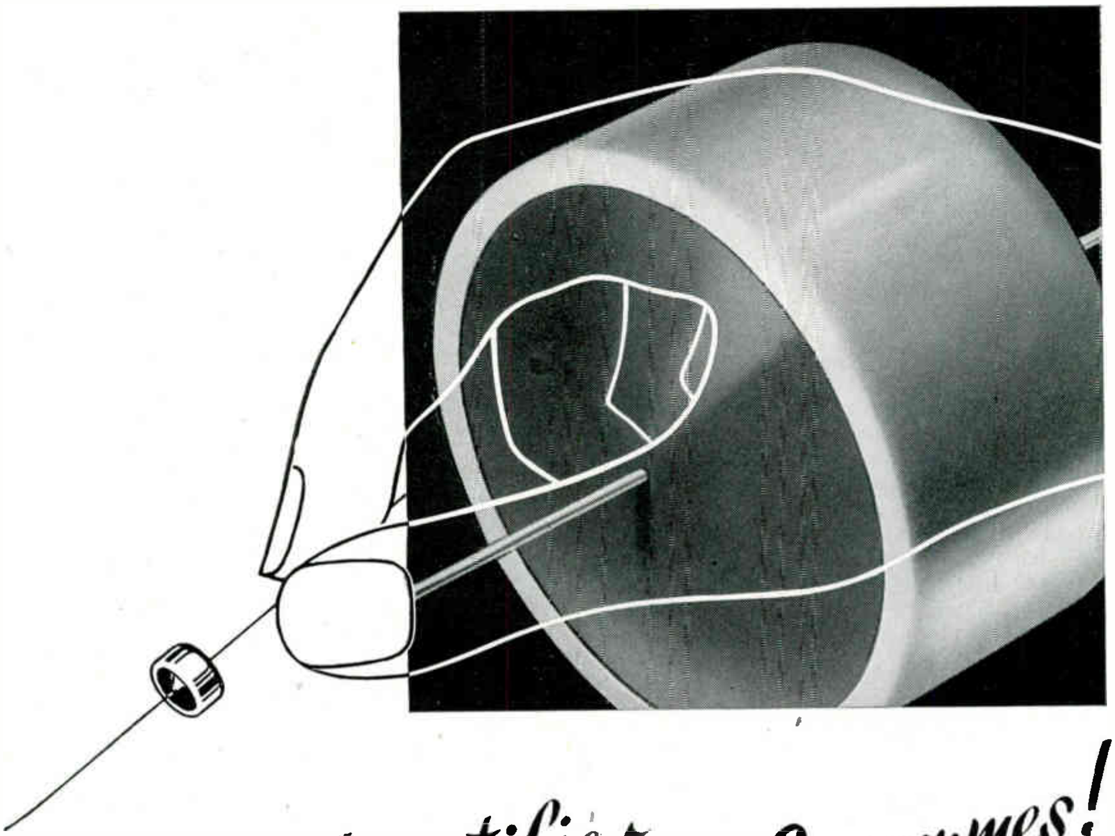
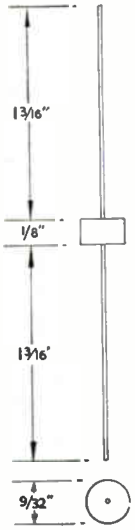
TYPE GVM 22 NO.
ZERO
RADIOMETER
COPENHAGEN
858F



this smallest rectifier weighs only 2grammes!



Only $\frac{9}{32}$ inch diameter and $\frac{1}{8}$ inch thick, this unusually small, single element SenTerCel rectifier, Type M-1, has been designed for use at input levels exceeding 0.5 volts at any frequency up to 5 Mc/s . . . weighs only 0.015 oz. Inexpensive, highly efficient, the M-1 in most cases will replace a thermionic rectifier, thus removing a source of heat as well as saving the cost and complication of a valve holder and its associated wiring.

AVERAGE CHARACTERISTICS

Self Capacitance	20 pf
Forward resistance at 5 V.D.C.	12 kΩ
Rev. resistance at 5 V.D.C.	20 MΩ
Max. peak inverse voltage	50 V
Min. A.C. input	0.5 V

SELENIUM
SenTerCel
RECTIFIERS
REGISTERED TRADE MARK

TYPE M-1

for A.F. Second detectors · A.G.C. rectifiers · Muting circuits · Contrast expansion and compression · Level indicators · Modulation depth indicators · Ringbridge modulators · Limiters · Automatic frequency control · Non-linear resistances.

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To Set Designers

R&A

Loudspeaker
Manufacturers
to the
radio industry
since 1930

Many of our component parts are standardized in order to simplify production and reduce costs. For example, voice-coils, centring members and pole-pieces are each made in only two diameters. Yet these and other standard parts can be assembled into a wide range of speakers, offering the set designer adequate choice of size, sensitivity, and performance—and at the same time showing clear advantages in both reliability and price.

With export needs in mind, overall diameters and mounting centres are aligned with American R.M.A. standards, so that R. & A. Reproducers can be used as service replacements in any part of the civilized world.

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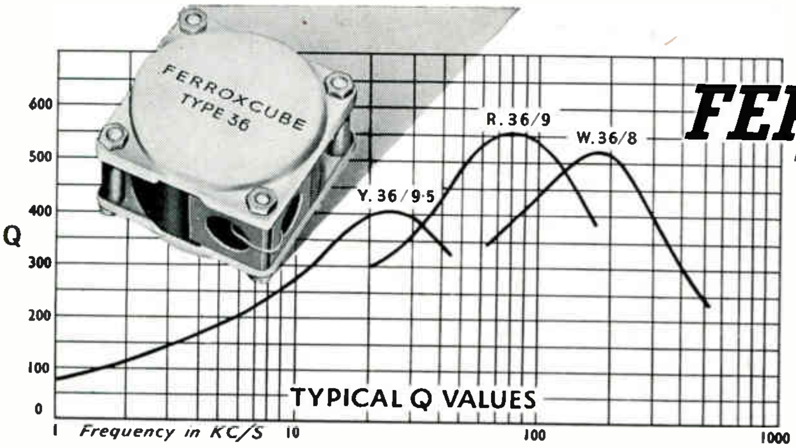

FERROXCUBE

FERROMAGNETIC FERRITE

For Line Communications :

In the design of Mullard pot core assemblies types 36 and 25 full advantage is taken of the characteristics of Ferroxcube to produce inductances of remarkably high "Q" factors. This, combined with ease of winding, makes these cores very suitable for use in filter networks and wherever high quality inductances are required.

Fine adjustment of inductance is obtained by control of the air gap rather than by variation of the turns.

The good screening properties of the Ferroxcube and the convenient shape of the assemblies, which allows stacking or individual mounting, are other features which distinguish these Mullard cores.

OUTSTANDING FEATURES

- ★ Low hysteresis coefficient
- ★ High values of inductance
- ★ Low self capacitance
- ★ Controllable air gap facilitating inductance adjustment
- ★ Self screening
- ★ Controlled temperature coefficient
- ★ Operation over a wide frequency range
- ★ Ease of winding and tapping
- ★ Easily mounted

PLEASE WRITE FOR FULL DETAILS

Mullard

Mullard FERROXCUBE
FERROMAGNETIC FERRITE

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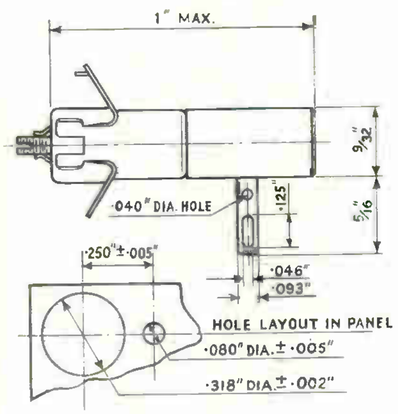
(MF375)

The ERIE* 531

for split-second assembly

A push with the finger and it's fixed!—and it's equally simple in design. Comprising only four parts, a combined mounting and earthing terminal, an adjustable inner electrode, a combined outer electrode and terminal and a moulded dielectric, yet it has all the essential requirements of a high frequency trimmer and compares more than favourably with articles of far greater complexity. Its capacitance change from maximum to minimum is practically linear, a feature which greatly assists production line adjustment and, despite its open construction, the 531 Trimmer has high resistance to tropical exposure.

RANGE (MOUNTED) : 1 to 8 PF and 0·5 to 5 PF
RATED WORKING VOLTAGE : 500 volts D.C
POWER FACTOR : Not greater than 0·12 %
INSULATION RESISTANCE : 10,000 megohms minimum
MAX. OPERATING TEMP. : 75°C



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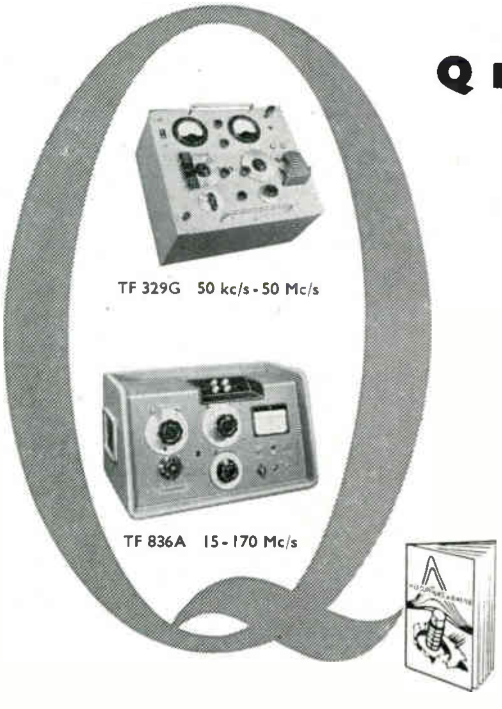
ERIE★ *Resistor Ltd*

CARLISLE ROAD, THE HYDE, LONDON, N.W.9. *Tel.:* COLindale 8011. *Factories: London and Great Yarmouth: Toronto, Canada; Erie, Pa., U.S.A.*



Q measurement by Marconi

Famous for years in the field of communication measurement, Marconi Instruments offer TF 329G for determinations in frequency range 50 kc/s to 50 Mc/s, and TF 886A for the range 15-170 Mc/s. While both instruments are primarily designed as direct reading Q meters, either may, of course, be employed for a variety of indirect measurements—such as the capacitance and phase defect of condensers — carried out by the normal resonance methods. In addition, special jigs are available for TF 329G for the investigation of dielectrics.

TF 329G	50 kc/s - 50 Mc/s	10 - 500 Q	40 - 450 $\mu\mu$F.
TF 886A	15 - 170 Mc/s	60 - 1200 Q	12 - 85 $\mu\mu$F.

May we send you our 44-page booklet **"Measurements by Q Meter"** ?

MARCONI instruments

SIGNAL GENERATORS · BRIDGES · VALVE VOLTMETERS
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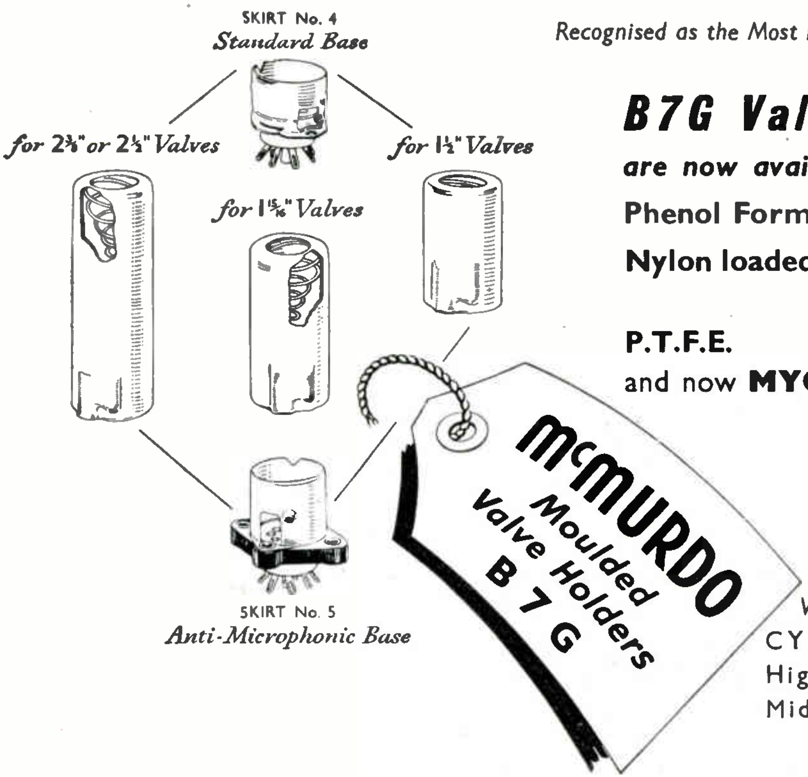

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B7G Valveholders

are now available moulded in:—

Phenol Formaldehyde *(Black).*

Nylon loaded Phenol Formaldehyde *(Natural Brown).*

P.T.F.E.

and now **MYCALEX.**

Wholesale Enquiries:—
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Manufacturers' Enquiries: THE McMURDO INSTRUMENT CO. LTD., VICTORIA WORKS, ASHTEAD, SURREY
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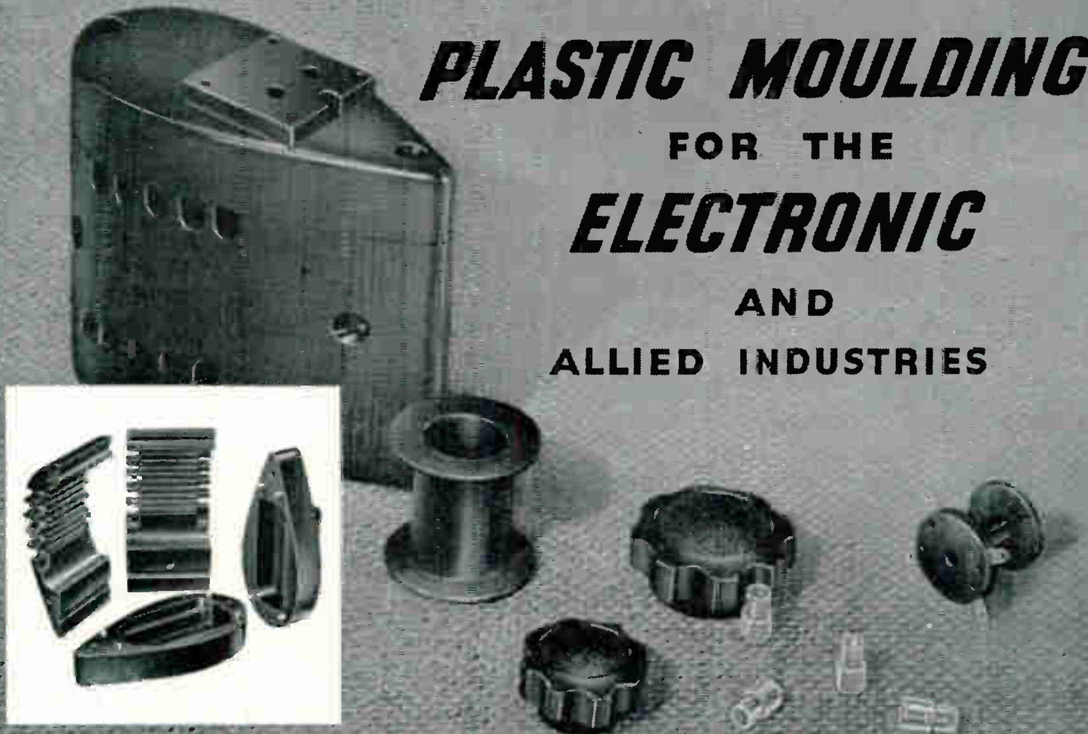
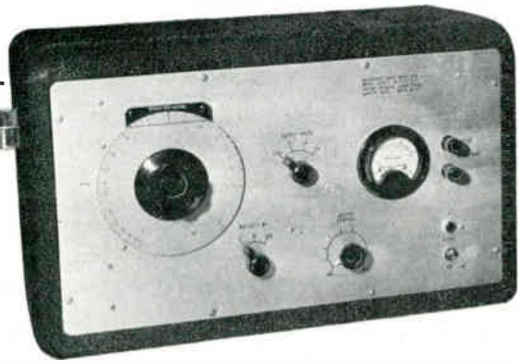



YOUR NAME ENGRAVED
OR ANY NAME-PLATE WORDING
IN THIS SPACE

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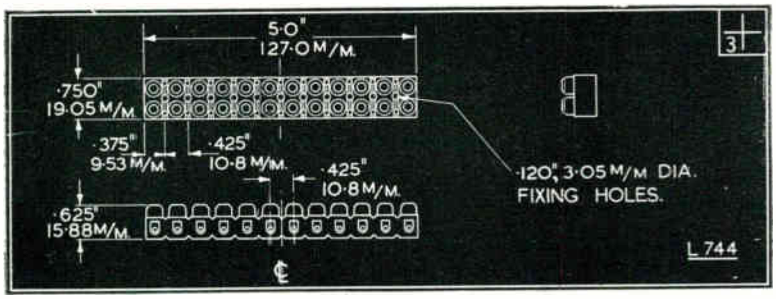
6851 KC/S

The "Belling-Lee" page for Engineers



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CAPTIVE TERMINAL SCREWS

FLEXIBLE

MECHANICALLY SHOCK-PROOF

EASILY SECTIONALISED

WIDE WORKING TEMPERATURE RANGE

FULLER DETAILS ON REQUEST

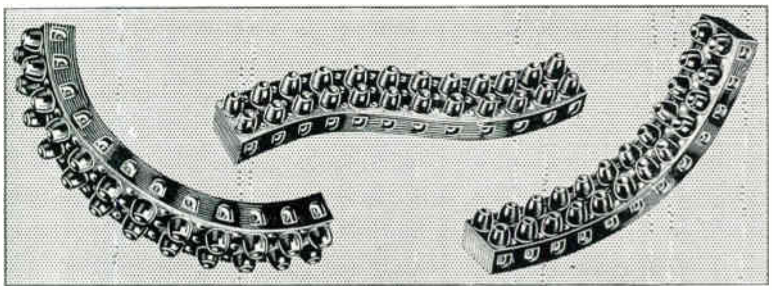
PLEASE QUOTE P378/WE

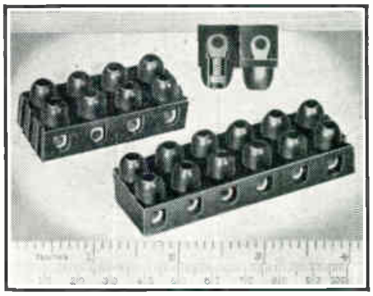
A UNIQUE 5-AMP FLEXIBLE TERMINAL BLOCK

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

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

Moulded in P.V.C., and in consequence very flexible, the moulding securely grips the terminal screws, which are so dimensioned that they cannot fall out, *even if totally unscrewed from their inserts and the block mounted upside down.*





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

The block is also mechanically shock-proof, the nature of the moulding rendering it safe against breakage due to vibration. It can easily be sub-divided with an ordinary knife, to make units up to 10-ways if required.

BELLING & LEE LTD
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SULLIVAN PORTABLE GALVANOMETERS

EMPLOYING A NEW

SUSPENDED COIL PORTABLE GALVANOMETER UNIT

which may be supplied alone or boxed complete with scale, illumination (with Mains Transformer) and novel Scale Magnification

These Galvanometers are also available as

DIRECT-READING
MICROAMMETERS
MILLIVOLTMETERS
and OHMMETERS

A compact, sensitive, yet robustly suspended galvanometer has been developed in our laboratories and, having undergone extensive trials, has proved to be extremely reliable for all purposes. All galvanometers are fitted with shock-absorbing non-sticking stops, thus overloads of up to 100 times full scale-current may be applied without risk of damage to the movement.

It is available as a compact unit for bench use, mounted in a bakelite case measuring only 12 × 8 × 4 cms. and is eminently suitable for mounting in the client's own equipment—a simple bracket mounting is incorporated to facilitate this.

It is available also in portable form in a polished teak case (complete with scale and illumination) with different internal optical arrangements of some novelty which give, in effect, various scale distances without having to resort to large awkwardly shaped boxes. In some cases effective scale-reading magnification of approximately 8 to 1 is obtained within a small box measuring only 27 × 16 × 16 cms. They may be used for all "null" balance measurements, such as for Wheatstone and Kelvin bridge work, in which case they are provided with centre zero scales. They may, however, if desired, be fitted with side zero scales for accurate deflection measurements—a high degree of law linearity rendering this possible.

Galvanometers covering the ranges	*Micro-ammeter 4 ranges*	*Milli-voltmeter 5 ranges*	*Ohmmeters covering the ranges*
COIL RESISTANCES 10 to 500 ohms	(full scale) 0 to 1 µA	(full scale) 0 to 1 mV	0 to 5,000 ohms
PERIODS 1·5 to 2 seconds	0 to 10 µA 0 to 100 µA	0 to 10 mV 0 to 100 mV	0 to 50,000 ohms 0 to 0·5 megohms
mm/µA 30 to 2,400	0 to 1,000 µA	0 to 1 V 0 to 10 V	0 to 50 megohms
	Period 2 seconds	Period 1 second	

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ENGINEERING

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The Journal of Radio Research and Progress

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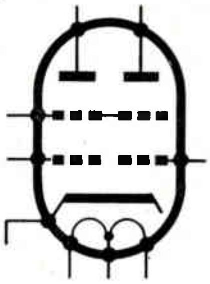


PRINCIPAL CHARACTERISTICS OF THE QQV03-20

HEATER

	Series	Parallel
V_h	12.6	6.3V
I_h	0.65	1.2A

CAPACITANCES

Each Section

$c_{g1\text{-all}}$	6.5 µµF
$c_{a\text{-all}}$	2.0 µµF

Two Sections in Push-Pull

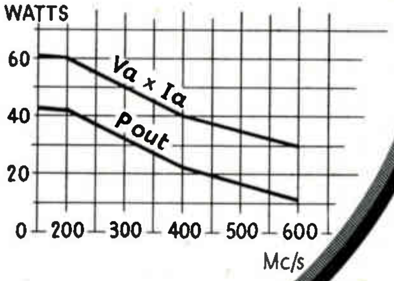
c_{out}	1.3 µµF
c_{in}	4.0 µµF

LIMITING VALUES

As Class " C " push-pull amplifier for C.W. Telegraphy or for F.M.

V_a max.	600 V
p_a max.	2 × 10 W
V_{g2} max.	250 V
p_{g2} max.	2 × 2 W
V_{g1} max.	-75 V
p_{g1} max.	2 × 0.5 W
I_k max.	2 × 55 mA
f max. (at reduced ratings)	600 Mc/s

BASE B7A



A high performance Double Tetrode for the new U.H.F. waveband allocations

PROVIDING 15 watts output at 500 Mc/s, and with an effective upper frequency limit of 600 Mc/s, this new Mullard double tetrode, the QQV03-20, is an ideal valve for communications equipment designed to operate in the new U.H.F. wave-band allocations.

As a result of new and important design features, this valve has the outstanding advantages of high anode efficiency, excellent power gain, low filament consumption, and small physical dimensions. In addition, being of conventional all glass technique, the QQV03-20 does not require the complex and expensive circuitry that is normally associated with the disc-seal type of U.H.F. valves.

This double tetrode has special advantages in compact communications equipment, where, due to its small size and low filament consumption, it enables maximum savings in space to be made.

Brief technical details of the QQV03-20 are given above. More comprehensive information will be gladly supplied on request.

Mullard

MULLARD LTD., COMMUNICATIONS & INDUSTRIAL VALVE DEPT., CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

MVT 126

WIRELESS ENGINEER

Vol. 29 SEPTEMBER 1952 No. 348

Electric Force and Potential Gradient

In the May 1952 number of the *Bulletin of Electrical Engineering Education*, published by the Manchester College of Technology, there is an article entitled "The Production of Electro-Motive-Force", throughout which there appears to be a surprising confusion between electric force and potential gradient. We are told that "the action of the betatron, no less than one's own common sense, indicates that a more fundamental conception must be that of the production of an electric field in the surrounding space whenever a magnetic field varies in value . . . In this case analysis of the results obtained in practice show that the relationship between E, the *potential gradient* of the consequent electric field, and $-d\phi/dt$, the flux variation which produces it, must necessarily be identical with the relationship between *magnetic force* H, and its originating current I." One would have thought that the difference between the two terms which we have italicized would serve as a warning that something was wrong, but the mistake occurs over and over again, either in the form of potential gradient or voltage gradient.

Fig. 1 may represent either an iron core, the magnetic flux in which is away from us and decreasing, or a conductor, the current in which is away from us. In the one case an electric field and in the other a magnetic field will be induced in the surrounding space, as indicated by the dotted circle. The strength of the field, that is, the electric or magnetic force, will be the same at all points on the circle, but this force is not due to any potential difference between different points on the circle. Strictly speaking, the term potential is not applicable to such cases of electromagnetic induction and there is no such thing as a potential gradient at any point on the circle. The same is true if the dotted circle represents a uniform closed ring of copper or iron; the current or flux at every point is due to the electric or magnetic force induced at the point, and not to any non-existent potential difference. In the article referred to, the author states that "the summation of the voltage gradient round a closed circuit is always equal to $-d\Phi/dt$"; surely it is obvious that the summation of the voltage gradient round a closed circuit must be zero. It would be interesting to know which of the two points A or B in Fig. 1 he would regard as being at the higher potential.

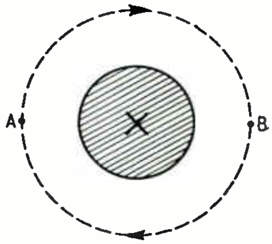


Fig. 1.

Those engaged in teaching elementary students will find a useful analogy in an annular trough containing water. If the trough is rotated about its vertical axis, the water will be set in motion due to the water-motive force produced by the friction between the water and the trough, but there is no difference of level or pressure between different points and therefore no gradient to account for the motion of the water.

G. W. O. H.

NATIONAL RADIO EXHIBITION

The 19th National Radio Exhibition, 26th August to 6th September, has again been held at Earls Court. Broadcast receiving equipment for both sound and television has formed the major part of the exhibition and a review of the apparatus will appear in the October issue of *Wireless Engineer*.

PRECISION VOLTAGE SOURCE

A.C. and D.C. Supplies for Amplifier Calibration

By V. H. Attree, B.Sc. (Eng.)

(Fluid Motion Laboratory, University of Manchester)

SUMMARY.—A tungsten-lamp non-linear bridge, run from a mains-transformer, provides a nearly-constant alternating voltage to a 100-Ω T-attenuator. The input-output characteristic of the bridge is parabolic and a mains-voltage change of ± 5% *reduces* the output voltage by 0·1%. For calibration the bridge is switched to a d.c. source, the voltage of which is adjusted by a lamp-comparator to equal the r.m.s. value of the a.c. supply. For best sensitivity of the lamp-comparator the working conditions are chosen from consideration of the properties of the human eye. Comparisons between a.c. and d.c. are made to within 2% which corresponds to a difference in bridge-output of only 0·02%. Over some months the bridge-output has remained constant to 1 part in 1 000.

Introduction

IN connection with some turbulence measurements a test-source was required to provide a rapid and accurate means of checking the gain of an amplifier. The gain check is to be made in 10-20 seconds and the precision of the source must be at least as good as the accuracy with which the amplifier output voltage is determined. The output voltage is measured with a thermojunction connected to a galvanometer and the galvanometer scale is read to 0·5 mm in a deflection of 100 mm. Hence, as the deflection is proportional to the mean-square of the output voltage, the accuracy of reading r.m.s. values is 1 part in 400.

During a period of a minute or so the voltage of the supply mains varies by as much as 1%, so that if we use a rheostat with a sub-standard voltmeter, it is quite impossible to obtain the required accuracy of calibration. A simple way out of the difficulty is to use a tungsten-lamp non-linear bridge; this will provide a nearly-constant output for a wide range of input voltages and, because it responds to the r.m.s. value of the supply, it will work equally well on either a.c. or d.c. The thermal non-linear bridge was first used to provide a stable supply by Campbell[1] some 50 years ago. The tungsten-lamp bridge has been described by Lewis,[2] Glynne,[3] and by Gage and Phillips.[4] The properties of the lamp itself are discussed by Patchett[5,6] and in a note by Turner.[7] An a.c. stabilizing arrangement using Metrosil discs is given by Martin and Maddock;[8] this device gives a high output but requires temperature compensation and offers no advantage in the present application.

In a non-linear element the voltage V and current I may be related by an equation of the form $V = KI^{\beta}$, where K and β are constants. From this equation we may easily show that $\beta V/I = \delta V/\delta I$. The term V/I is the 'static resistance' R_0 and the term $\delta V/\delta I$ is the 'dynamic resistance' R_D. For tungsten-filament lamps the constant β is between 1·6 and 1·7 in value.[3,5,6] Fig. 1 shows the circuit of a non-linear bridge; R_1, R_2 and R_3 are ordinary wire-wound resistances and L is the lamp. If the input voltage to the bridge is gradually raised the output will increase until the bridge is balanced for voltage *changes*. This occurs when $R_1 R_3 = R_2 R_D$ where R_D is the dynamic resistance of the lamp. Further increase of the input voltage will cause the output to fall as the lamp resistance increases until, when $R_1 R_3 = R_2 R_0$ the output is zero. This second condition is the one in which non-linear bridges are used as voltage-indicators in a.c. stabilizers.[3,5] The dynamic resistance R_D does not change rapidly with applied voltage so that, at the maximum-output condition, the output varies slowly with input-voltage, and the device gives a nearly-constant output for a range of input voltages. A more detailed account of the theory of non-linear bridges has been given elsewhere.[1,3,4]

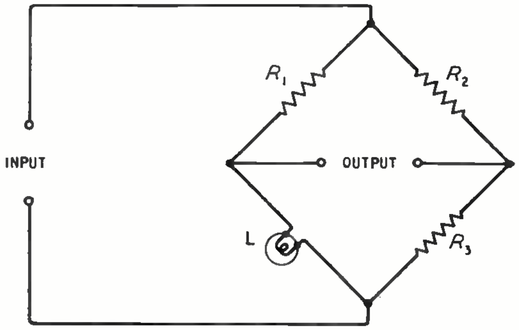


Fig. 1. *Circuit of non-linear bridge.*

With a non-linear bridge of the type shown in Fig. 1 the efficiency is only about 0·5%. If, however, R_2 is replaced by a lamp identical with L the efficiency is improved to 2%. In the present case efficiency is not important and a single lamp is used.

MS accepted by the Editor, December 1951

Circuit Description

It has been pointed out by Turner[7] and by Patchett[6] that if a tungsten-filament lamp is run at about one-half of its nominal voltage excellent long-term stability is obtained and, furthermore, the effect of ambient-temperature changes is small. In the present case the lamp is a 6·3-V 0·04-A torch bulb and at 3 V its dynamic resistance R_D is about 100 Ω. The best power efficiency is obtained when the resistances R_1, R_2 and R_3 (Fig. 1), together with the dynamic resistance R_D, are equal to each other and to the load resistance. This means that the output impedance may be taken as 100 Ω, which is a convenient characteristic impedance to use in the T-attenuator.

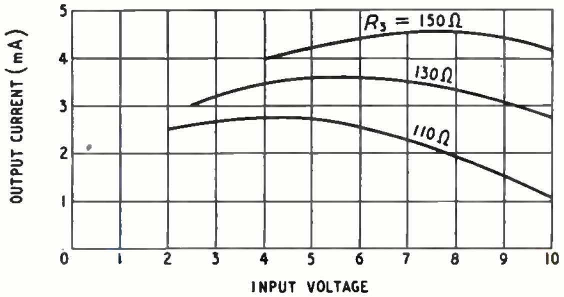


Fig. 2. *Input/output relationship for non-linear bridge;* $R_1 = R_2 = 100\Omega$, $L = 6{\cdot}3$-*V*, 0·04-*A torch bulb, output current measured in* 100-Ω *load.*

Fig. 2 shows the input-output relation with $R_1 = R_2 = 100\ \Omega$ and for several values of R_3. It will be seen that the balance point occurs at a higher voltage as R_3 is increased. In the practical circuit, Fig. 3, R_3 is 110 Ω, which gives a voltage-maximum for a supply of approximately 4·0 V r.m.s. The calibrator normally runs from a 6·3-V secondary winding and the balance-point is set by adjustment of the series resistance R_4.

The Attenuator

The non-linear bridge is followed by an attenuator with a total range of 80 db adjustable in 2-db steps; the output of the bridge is approximately 300 mV so that the smallest signal available is 30 μV. The attenuator consists of three 20-db T-pads having a characteristic impedance of 100 Ω, followed by an output potentiometer giving ten steps each of approximately 2·0 db. The half-series resistances R_5, R_6, etc., of the T-pads have a nominal value of 81·818 Ω, while the shunt resistances R$_7$, etc., are 20·202 Ω. The overall accuracy of the output voltage calibration is 1 part in 1,000 (0·1%). The effect of errors in the resistance values is discussed in the Appendix. A given ohmic error in the shunt arm changes the output voltage by 8·1 times as much as does the same error in the series arm. With the resistance boxes available it was found that the attenuator resistances could not be adjusted to a tolerance much better than 0·1 Ω. An error of this amount in R_5 or R_6 affects the output voltage by −0·05%, while the same error in R_7 alters it by +0·41%. In order to obtain the required final accuracy the input and output voltages of each T-pad were measured with a d.c. potentiometer (reliable to 1 part in 5,000) and the attenuation was brought to the exact value by adjustment of the shunt resistances.

The 2·0-db steps, for fine adjustment of the attenuation, are obtained by the resistances R_{14}—R_{23}. These resistances are adjusted to within about 0·1 Ω of their nominal values; the sum of all the resistances in the chain is made exactly 100 Ω by adjustment of R_{23}. The exact value of the attenuation for each step is obtained with a potentiometer.

All resistances are wound on thin paxolin strips and the windings are held in place with shellac. At frequencies up to 10 kc/s the error in attenuation, due to stray reactances, cannot be measured by the available equipment and is certainly less than 0·2%. The phase change can just be detected with all three T-pads in circuit; at 10 kc/s it is 1 degree. From these measurements it is reasonable to assume that the attenuation at 50 c/s is substantially the same as the value derived from measurements with a d.c. potentiometer.

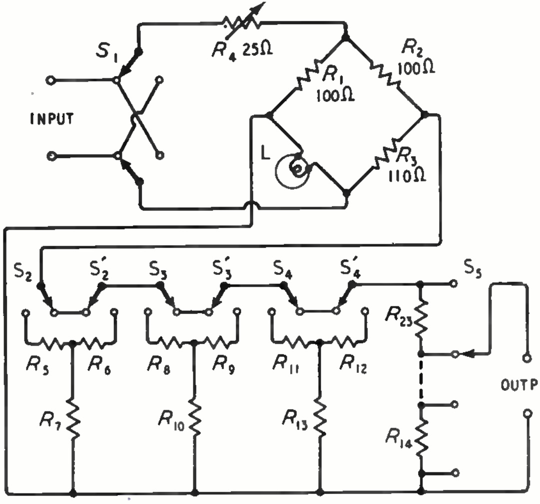


Fig. 3. *Circuit diagram of non-linear bridge and attenuator;* R_5, R_6, R_8, R_9, R_{11}, $R_{12} = 81{\cdot}82\Omega$; R_7, R_{10}, $R_{13} = 20{\cdot}20\Omega$; $R_{14} = 10\Omega$; $R_{15} = 2{\cdot}9\Omega$; $R_{16} = 3{\cdot}7\Omega$; $R_{17} = 4{\cdot}9\Omega$; $R_{18} = 6{\cdot}2\Omega$; $R_{19} = 8{\cdot}0\Omega$; $R_{20} = 10{\cdot}4\Omega$; $R_{21} = 13{\cdot}4\Omega$; $R_{22} = 17{\cdot}5\Omega$; $R_{23} \doteq 23{\cdot}0\Omega$; $L = 6{\cdot}3$-*V*, 0·04-*A bulb;* S_2, S_3, S_4 *2-pole, 2-way;* S_5 *1-pole, 11-way.*

Measurement of Hum

The purpose of the commutating switch S$_1$, Fig. 3, is to provide a means of estimating the amplitude of the unwanted hum pick-up in the amplifier. Consider a test signal of *A* volts and an interfering signal of KA volts in an amplifier with a thermocouple output stage. Then, if the two signals are in phase the output of the thermocouple will be proportional to $A^2(1+K)^2$, and if they are in antiphase the output will be $A^2(1-K)^2$. The mean of the two deflections is proportional to $A^2(1+K^2)$, and their difference is proportional to $4A^2K$. In general the fraction K is fairly small so that K^2 may be neglected as compared with unity. Thus the difference of the two output readings, divided by their mean, is simply $4K$. Clearly this is a remarkably sensitive method of detecting hum pick-up, as a difference of 1% in the two galvanometer readings (which is easily detected) corresponds to an interfering hum-level of only 0·25%. The discussion given above is based on the assumption that the interfering signal is either in phase or antiphase with the test signal. Fortunately quite a large deviation from this condition is not important as the hum-level is normally quite small. An exact measurement of hum may be obtained by inserting a phase-shifter in the supply to the non-linear bridge and finding the maximum and minimum values of the thermocouple output. Another method of measuring the hum-level is to feed the non-linear bridge from a stable low-frequency oscillator set at a frequency slightly different from that of the mains. The amplitude of the slow output-beat divided by the mean deflection is $4K$, as before. The oscillator used must be free from hum and should have a fine control for frequency.

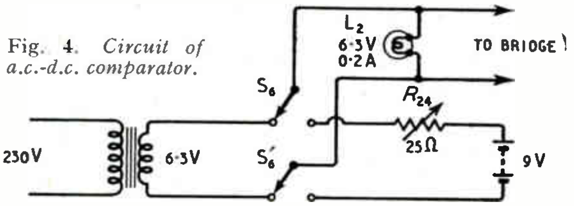


Fig. 4. *Circuit of a.c.-d.c. comparator.*

The Bridge Accuracy

The input-output voltage relation for the non-linear bridge was measured with a d.c. potentiometer. For input voltages within 20% of the nominal value, the graph of output voltage against input voltage is parabolic. The percentage error p, arising from a percentage deviation of q in the input, is given by the relation: $p = -q^2/200$. Thus a change in supply voltage of 1% *reduces* the output by 0·005% and a change of 10% *reduces* it by 0·5%. The performance of the bridge described by Glynne,[3] and of other tungsten-lamp bridges used by the author (for stabilizing photometer lamps) fit the same equation.

Harmonic Content

The temperature of the lamp filament, and hence its resistance, varies slightly during the a.c. cycle; this gives rise to an unwanted harmonic component in the output. The effect has been analysed by Glynne[3] and by Patchett[5] who have derived expressions in terms of the parameters of the lamp. For our purpose it is sufficient to write the unwanted output appearing with a wanted output of $V_0 \sin \omega t$ in the form: $V_0 [\cos 3\omega t - \cos \omega t] K/\omega$. The first term in the bracket is the third harmonic and the second term is a quadrature component of equal amplitude. The value of the constant K is determined by the type of lamp used and the circuit conditions. For the circuit of Fig. 3 K/ω is about 1% at 50 c/s. A harmonic content of 1% represents an error of only 0·01% (1 part in 10,000) on the thermocouple instrument. The quadrature component will cause the output voltage to increase slightly at low frequencies; this effect is negligible at 50 c/s. The harmonic content of a non-linear bridge may of course be reduced by using a non-linear element with a longer thermal time-constant. As an example, if the heater of an EA50 (CV1092) is used for the non-linear element and $R_1 = R_2 = 30\ \Omega$; $R_3 = 60\ \Omega$ (Fig. 3), then the bridge balances at an input of 6·0 V and delivers 0·7 V into a 100-Ω load. The time-constant is now about 20 sec and even at frequencies as low as 1 c/s the harmonic content is very small. Similar results may be obtained with thermistors, but these have the disadvantage that compensation for ambient temperature changes is essential. Barretters will also give a long time-constant, but they are liable to sudden unexplained changes of output and are unduly sensitive to mechanical shock.

The A.C.-D.C. Comparator

The output of the non-linear bridge depends only on the r.m.s. value of the input, thus the bridge may be calibrated on d.c. with a potentiometer and a standard cell. Some form of transfer instrument is needed to permit the d.c. input to the bridge to be made the same as the alternating voltage from the transformer. If we wish the outputs of the bridge on a.c. and d.c. to agree within 1 part in 1,000 (0·1%) then, from the formula previously given, the inputs must be within 4·5% of equality. This accuracy is obtained by using a lamp as a transfer instrument. The circuit is shown in Fig. 4; the toggle switch S_6 enables us to switch the non-linear bridge rapidly from a.c. to d.c. The variable resistance R_{24} in the d.c. circuit is adjusted until the brightness of the lamp L_2 is the same on a.c. and d.c.

The use of a lamp as an a.c.-d.c. comparator is not well known and it is worth while examining the conditions which determine the sensitivity. The light output of a heated tungsten-filament, as a function of applied voltage, may be derived from the tables of Jones and Langmuir.[9] We are interested in the quantity $M = (V/B)(\delta B/\delta V)$; i.e., the percentage change in brightness for a 1% change in supply voltage. The value of M, as calculated for a range of applied voltages, is between 3 and 4. From this it appears that there is not much advantage in running the lamp at a voltage different from its usual value.

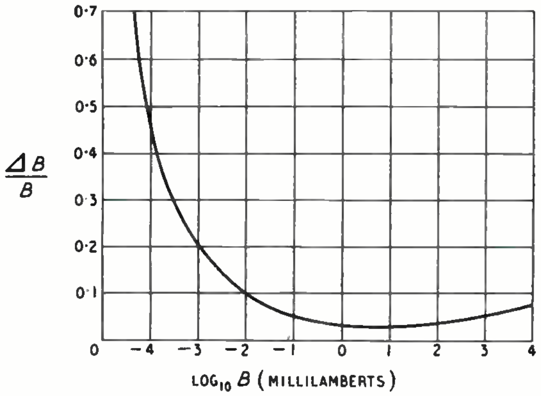


Fig. 5. *Relation between light-intensity B and brightness-difference threshold $\Delta B/B$.*

The ability of the human eye to distinguish small changes of brightness at different brightness levels is shown in Fig. 5. The curve is based on a paper by Hecht[10] who reviewed the classical work on the subject. A similar curve is given in most modern books on vision; e.g., Hartridge.[11] It will be seen that for a range of light-intensity B from 1 to 1,000 millilamberts ($\log_{10} B = 0$ to 3) the brightness-difference threshold $\delta B/B$ is approximately 3%. The field of view should subtend an angle of 1 degree (or more) and the brightness of the test patch must not differ too greatly from the brightness of the ambient light. The curve of Fig. 5 relates to light-intensities presented simultaneously in the test field. In our case the light intensities are seen in turn and it would be expected that, under these conditions, the minimum detectable difference in brightness would be somewhat larger.

The lamp arrangement used consistsf oa 1·2-W bulb mounted 2 in. behind a diffusing screen 1 in. in diameter. The screen brightness is about 30 millilamberts and at a viewing distance of 12 in. the angle subtended is 5 degrees. With this set-up R_{24} may be adjusted so that the direct input voltage to the bridge is within 2% of the alternating voltage. This accuracy is more than sufficient to ensure that the bridge outputs on a.c. and d.c. agree to within 1 part in 1,000.

Applications

For most purposes the high accuracy aimed at in the calibrator is unnecessary and the non-linear bridge may be used without provision for calibration. The simple bridge of Fig. 1, with R_3 at 130 Ω, balances at 6·3 V and may be used to stabilize an oscillator output or to provide a calibration voltage on an oscilloscope. The inductance of the lamp is small and if suitable resistances are used there is no difficulty in working the bridge at radio frequencies.

APPENDIX

Attenuator Errors:

If Z_0 is the characteristic impedance of the T-pad R_1, R_2 and R_3 shown in Fig. 6 and $K = V_2/V_1$ then the correct values of the resistances are given from the usual design formulae :—

$$R_1 = R_2 = Z_0 \frac{1-K}{1+K} \quad \cdots \quad (1)$$

$$R_3 = 2Z_0 \frac{K}{1-K^2} \quad \cdots \quad (2)$$

In the present case $K = 0{\cdot}1$, $Z_0 = 100\ \Omega$ and the accurate values are $R_1 = R_2 = 81{\cdot}818\ \Omega$; $R_3 = 20{\cdot}202\ \Omega$.

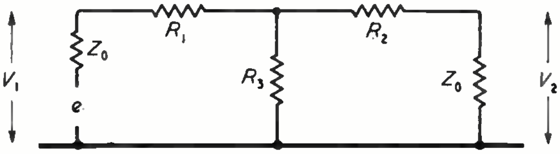


Fig. 6. *Equivalent circuit for T-attenuator.*

The output resistance of the non-linear bridge is approximately 100 Ω so that for the purpose of estimating the effects of errors we shall represent the input circuit of the attenuator as a constant e.m.f. e in series with a resistance Z_0. If we let N be the ratio V_2/e then for an error in either R_1 or R_2 we find:—

$$\frac{\delta N}{N} = -\frac{\delta R_1}{R_1} \cdot \frac{R_1}{2Z_0} \quad \cdots \quad (3)$$

and for an error in R_3

$$\frac{\delta N}{N} = \frac{\delta R_3}{R_3} \cdot \frac{Z_0 + R_1}{Z_0 + R_1 + 2R_3} \quad \cdots \quad (4)$$

Equations (3) and (4) may be expressed directly in terms of the attenuation factor K as follows:—

$$\frac{\delta N}{N} = -\frac{\delta R_1}{R_1} \cdot \frac{1-K}{2(1+K)} \quad \cdots \quad (5)$$

$$\frac{\delta N}{N} = \frac{\delta R_3}{R_3} \cdot \frac{1-K}{1+K} \quad \cdots \quad (6)$$

When $K = 0{\cdot}1$ (i.e., for a 20-db pad) $\frac{1-K}{2(1+K)} = 0{\cdot}409$ and $\frac{1-K}{1+K} = 0{\cdot}818$. Thus a 1% error in R_1 (or R_2) *decreases* the output voltage by 0·41% while a 1% error in R_3 *increases it* by 0·82%.

In practice we are usually able to adjust low-valued resistances to within a certain ohmic (rather than percentage) tolerance, and it is interesting to interpret equations (5) and (6) in this form. Let the resistances be adjusted to within δR ohms of the correct value, then:—

$$\left.\begin{array}{c}\text{For changes in}\\ R_1 \text{ or } R_2\end{array}\right\} \frac{\delta N}{N} = -\frac{\delta R}{2Z_0} \quad \ldots (7) \quad \text{[from equation (3)]}$$

$$\left.\begin{array}{c}\text{For changes in}\\ R_3\end{array}\right\} \frac{\delta N}{N} = \frac{\delta R}{2Z_0} \cdot \frac{(1-K)^2}{K} \quad (8) \quad \text{[from equations (2 \& 6)]}$$

When $K = 0{\cdot}1$ the factor $(1 - K)^2/K$ in equation (8) is 8·1, thus we arrive at the final result that, with a 20-db pad, a small change in the shunt arm affects the output 8·1 times as much as the same change in either of the series arms. In the case of $Z_0 = 100\ \Omega$ and $K = 0{\cdot}1$ we find that a 0·1-Ω error in R_1 or R_2 reduces the output voltage by 0·05% while the same error in R_3 increases it by 0·41%.

It is stressed that the above relations are applicable only where the source impedance is taken into account (as in Fig. 6). If this impedance is appreciably different from Z_0, or alternatively if the input voltage V_1 is maintained constant, then the effect of resistance errors is not the same and a new analysis is necessary.

REFERENCES

[1] Campbell, A., "On Test Room Methods of A.C. Measurement", *J. Instn elect. Engrs*, Vol. 30, p. 889, 1901.

[2] Lewis, F. G. H., "An Automatic Voltage Regulator", *Proc. Phys. Soc.*, Vol. 34, p. 17, 1921.

[3] Glynne, A., "A Differential Electronic Stabilizer", *J. Instn elect. Engrs*, Vol. 90, Pt. II, p. 101, 1943.

[4] Gage, F. H., and Phillips, G. J., ". . . an Alternating Current Standard Cell", *Phil. Mag.*, Vol. 38, p. 398, 1947.

[5] Patchett, G. N., "Theory of Non-linear Bridge Circuits as applied to Voltage Stabilizers", *J. Instn elect Engrs*, Vol. 93, Pt. III, p. 16, 1946.

[6] Patchett, G. N., "The Characteristics of Lamps. . .", *J. Instn elect. Engrs*, Vol. 93, Pt. III, p. 305, 1946.

[7] Turner, L. B., Discussion, *J. Instn elect. Engrs*, Vol. 78, p. 528, 1936.

[8] Martin D. J. R., and Maddock, A. J., "A Low Power Alternating-Voltage Stabilizer", *J. sci. Instrum.*, Vol. 28, p. 1, 1951.

[9] Jones, H. A., and Langmuir, I., "The Characteristics of Tungsten Filaments as a Function of Temperature", *Gen. elect. Rev.*, Vol. 30, p. 310, 1927.

[10] Hecht, S., "The Visual Discrimination of Intensity and the Weber-Fechner Law", *J. Gen. Physiol.*, Vol. 7, p. 235, 1925.

[11] Hartridge, H., "Recent Advances in the Physiology of Vision". (London, J. & A. Churchill, 1950), p. 122.

SURFACE-WAVE TRANSMISSION LINES

By A. C. Grace, A.M.I.E.E., and J. A. Lane, B.Sc.

(Communication from the National Physical Laboratory)

SUMMARY.—The paper describes experiments with various types of single-conductor transmission line at radio frequencies of 3,300 and 9,400 Mc/s. The lines consisted of lengths of 18 s.w.g. bare, tinned and enamelled copper wire with launching and receiving horns of small flare angle. The results show good agreement with the theoretical work of Goubau and confirm the efficiency of the dielectric-coated wire as a waveguide at these frequencies.

1. Introduction

THE Editorial in the July 1950 issue of this journal has already drawn attention to the use of the single-conductor transmission line as an efficient waveguide for very high radio frequencies. Its operation depends on the excitation of a non-radiating surface wave of the type studied theoretically by Sommerfeld in 1899, which is guided by a conductor of finite conductivity. The work of Goubau[1,2] has shown that a similar wave can be launched on a cylindrical conductor of large or infinite conductivity if the surface is suitably modified by adding a dielectric layer or cutting a screw thread. These serve to reduce the phase velocity slightly and restrict the spatial extension of the field. Goubau's results for enamelled wire 2 mm in diameter show, for example, that at frequencies between 1,000 and 5,000 Mc/s the total loss in a transmission line 37 m long and with an enamel thickness of 0·05 mm is of the order of 2 db. The authors have recently made similar measurements at frequencies of 3,300 and 9,400 Mc/s on some specimens of bare, tinned and enamelled wire and their results are summarized below.

2. Experimental Procedure and Results

The wires formed at their extremities the inner conductor of a concentric-line system, the outer conductor being a conical horn of small flare angle as shown in Fig. 1. Measurements were made of the oscillator output power and the received power for various lengths of wire by bolometer bridge technique, similar to that described by Saxton and Grace,[3] using a CV.95 type bolometer operated at a constant resistance of 40 ohms.

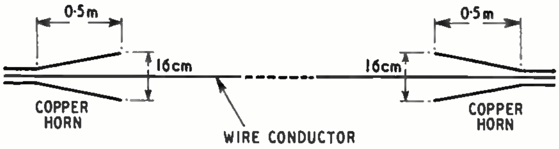


Fig. 1. *Experimental surface-wave transmission line.*

The measured losses are due to (1) launching and receiving losses associated with the horns, and (2) conductor and dielectric losses in the guide. With a transmission line of given diameter, the horn losses are reduced to a minimum by increasing the thickness of dielectric coating: in the case of 18 s.w.g. enamelled wire at 3,300 Mc/s these losses amount to about 1 db per horn with the

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dimensions shown but, quite apart from other factors, increasing dielectric loss sets an upper limit to the thickness of coating for efficient transmission.

The experimental results for the horn and line losses are compared in Table 1 with those calculated from Goubau's treatment assuming a perfectly smooth wire surface, the theoretical figures for tinned-copper wire being obtained by making the necessary change in the surface resistivity term.

TABLE 1

Losses in Single-Conductor Transmission Line

f (Mc/s)	Wire	Wire Loss (db/m)		Total Horn Loss (db)	
		Expt.	Theory	Expt.	Theory
3,300	18 s.w.g. polished 18 s.w.g. tinned copper 18 s.w.g.e namelled copper	0·016 0·11 0·07	0·012 0·12 0·06	3·3 3·6 2·1	3·4 2·7 2·2
9,400	18 s.w.g. tinned copper 18 s.w.g. enamelled copper	0·37 0·26	0·23 0·15	1·8 1·0	1·5 0·2

The excellent agreement between theory and experiment at 3,300 Mc/s for the horn loss with polished and enamelled wire is probably somewhat fortuitous, as the experimental accuracy in power measurement is not better than about 10%. The maximum discrepancy occurs at the higher frequency, and in the case of the enamelled wire loss this may arise from the uncertainty regarding the appropriate value of dielectric loss angle. The theoretical figures for horn losses take no account, of course, of any losses due to inefficient matching in the transmitting and receiving systems.

In addition an experiment was performed to investigate the loss due to bends in the wire. A length of 7 m of enamelled wire was bent into an arc of a circle of 14 m radius giving a total angle of about 30° between the horn axes, and at a frequency of 3,300 Mc/s the total loss increased from 2·5 to 5·0 db.

3. Conclusions

The results summarized above confirm the efficiency of the dielectric-coated wire as a waveguide for very high radio frequencies when used in conjunction with suitable launching and receiving horns. The results also confirm the general validity of the existing theoretical treatment. With an enamelled-wire transmission line as shown in Fig. 1 the maximum total horn losses for radio frequencies between 3,000 and 9,000 Mc/s would be about 2 db, coupled with a line loss varying from 0·07 to 0·26 db/m and increasing with frequency.

4. Acknowledgments

The work described above was carried out as part of the programme of the Radio Research Board. This paper is published by permission of the Director of the National Physical Laboratory, and the Director of Radio Research of the Department of Scientific and Industrial Research. The authors desire to acknowledge the advice given by Dr. J. A. Saxton during the investigation.

REFERENCES

[1] Goubau, G. "Surface Waves and their Application to Transmission Lines." *J. Applied Physics*, 1950, Vol. 21, p. 1119.
[2] Goubau, G. "Single Conductor Surface Wave Transmission Line." *Proc. Inst. Radio Engrs*, 1951, Vol. 39, No. 6, p. 619.
[3] Saxton, J. A., and Grace, A. C. "A Field-Strength Meter and Standard Radiator for Centimetre Wavelengths." *J. Instn elect. Engrs*, 1946, Vol. 93. Part IIIA, No. 9, p. 1426.

PREMIUMS FOR TECHNICAL WRITING

The first of the Radio Industry Council's premiums for technical writing has been awarded to J. R. Acton, B.Sc., Grad.Brit.I.R.E., of the Ericsson Research Laboratories, Nottingham, for his paper "The Single-Pulse Dekatron," published in *Electronic Engineering*, February 1952. The presentation of the award of 25 guineas was made at a luncheon at the Radio Exhibition on 1st September.

Further awards are to be announced at the end of the year; they are to be made to the writers of published articles which deserve to be commended by the industry, and any non-professional writer of articles published in journals or periodicals available to the public from bookstalls or by subscription is eligible.

MAGNETRON EFFECT IN HIGH-POWER VALVES

Squirrel-Cage Filament Structure

By A. M. Hardie, M.A., B.Sc., A.M.I.E.E.

(*Metropolitan-Vickers Electrical Co. Ltd.**)

SUMMARY.—In this paper the resultant magnetic field in the neighbourhood of a squirrel-cage filament structure is first calculated and the results applied to formulate an approximate theoretical treatment of magnetron effect in large valves in which this type of filament is used.

The theoretical treatment is here restricted to the diode condition (anode and grid strapped) since it becomes intractable for the triode when grid and anode have different potentials.

Some experimental evidence is adduced in support of the approximate theory. The triode case is then investigated experimentally by a pulse method and a qualitative explanation of the observed results is given.

1. Introduction

In transmitting valves of medium and high power the filament-heating current may be of the order of hundreds of amperes. The magnetic field of such a heating current affects the electron trajectories and hence the valve characteristics.

When the filament is heated by a.c., the valve characteristic varies between that at zero field and that at maximum field at twice the supply frequency, grid and anode currents being modulated at a fundamental frequency of 100 c/s if 50-c/s single phase a.c. is employed. The nature of the modulation is complex, depending on the instantaneous relative values of the electrode potentials, and the effect is greatest at low electron velocity; i.e., at low electrode potentials.

Magnetron effect is briefly mentioned in the literature, but there appear to be practically no published experimental or analytical investigations. Bell, Davies and Gossling[1] in their paper of 1938 give an instance of two valves having similar electrode geometry but different filament currents, and ascribe the divergence of the grid-current characteristics to a change in magnetron effect.

The effect on transmitter performance may be partly alleviated by connecting the filaments in 3-phase, although triple-multiple harmonics[1] are still present. This naturally requires redesign of the filament structure.

In a balanced radio-frequency amplifier it has been found that the magnetron modulation is much reduced by operating the two single-phase filaments in quadrature from Scott-connected transformers, the 100- and 300-c/s components being thereby eliminated.

The avoidance of magnetron modulation is of importance in television transmitters, and for this reason the filaments of the final amplifiers are usually heated by direct current.

2. Calculation of the Magnetic Field Near a Squirrel-Cage Filament Structure

Since the magnitude of magnetron effect on the valve performance is dependent on the residual magnetic field of the filament structure, it is appropriate first to develop a general expression for the magnetic field near a system of conductors in the form of a squirrel cage. We shall suppose that the length of the structure is long compared to its diameter, that there is an even number of conductors equally spaced round the periphery of a circle, and that adjacent conductors carry equal and oppositely-directed currents. This type of structure is usual in large transmitting valves having pure tungsten filaments, the number of conductors varying from 4 to 16.

Referring to Fig. 1, which is a section normal to the axis of the squirrel cage, let

a = pitch circle radius of filament wires,
n = number of wires (even),
I = current in each wire,
H_t = tangential component of magnetic field,
H_r = radial component of magnetic field,
ψ = magnetic potential.

Consider the magnetic field due to a single wire at A $(a, 0)$, at the point $(r, 0)$ on OA produced, so that $r > a$. Then if $(r - a) \ll l$, the length of the wire, we have

$$H_t = \frac{2I}{r-a} = \frac{2I}{r} \sum_{\kappa=0}^{\infty} \left(\frac{a}{r}\right)^{\kappa}, \quad \ldots \quad \ldots \qquad (1)$$

and $H_r = 0$, since the field is wholly tangential.

In plane polar co-ordinates ψ must satisfy

$$\nabla^2 \psi = 0 \quad \ldots \quad \ldots \quad \ldots \qquad (2)$$

at any point in space, a general solution of equation (2) appropriate to this problem being

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$$\psi = A_0\theta + \sum_{\kappa=1}^{\infty} (A_\kappa r^\kappa + B_\kappa r^{-\kappa}) \sin \kappa\theta \quad .. \qquad (3)$$

Then,

$$H_t = -\frac{1}{r}\frac{\delta\psi}{\delta\theta} = -\frac{A_0}{r} - A_1 \cos\theta - 2A_2 \cos 2\theta - ..$$

$$.. -\frac{B_1}{r^2}\cos\theta - \frac{2B_2}{r^3}\cos 2\theta - \quad .. \quad .. \qquad (4)$$

When $\theta = 0$, this expression for H_t must reduce to that given by equation (1); i.e.,

$$H_t = \frac{2I}{r}\left(1 + \frac{a}{r} + \frac{a^2}{r^2} + \ldots.\right) \quad .. \qquad (5)$$

On comparing equations (4) and (5) we have $A_0 = 2I$, $B_1 = -2Ia$, $B_2 = -2Ia/2$, etc., and $A_1 = A_2 = A_3 = \ldots\ldots = 0$.

Hence

$$\psi = -2I\left(\theta + \frac{a}{r}\sin\theta + \frac{a}{2r}\sin 2\theta + \ldots.\right) \qquad (6)$$

$$H_t = -\frac{1}{r}\frac{\delta\psi}{\delta\theta} = \frac{2I}{r}\left(1 + \frac{a}{r}\cos\theta + \frac{a^2}{r^2}\cos 2\theta + \ldots.\right) \quad .. \quad .. \qquad (7)$$

$$H_r = -\frac{\delta\psi}{\delta r} = -\frac{2I}{r}\left(\frac{a}{r}\sin\theta + \frac{a^2}{r^2}\sin 2\theta + \ldots.\right) \quad .. \quad .. \quad .. \qquad (8)$$

H_t and H_r are here the field components at the point (r, θ) for a single wire at the point $(a, 0)$.

When the effects of all the wires at (r, θ) are summed, each term of the infinite series (7) and (8) consists of the sum of n terms having alternating signs, since the currents in adjacent wires are in opposite directions. We must therefore find the sum of these individual n-term series and then attempt to sum the infinite series in order to obtain a solution in closed form.

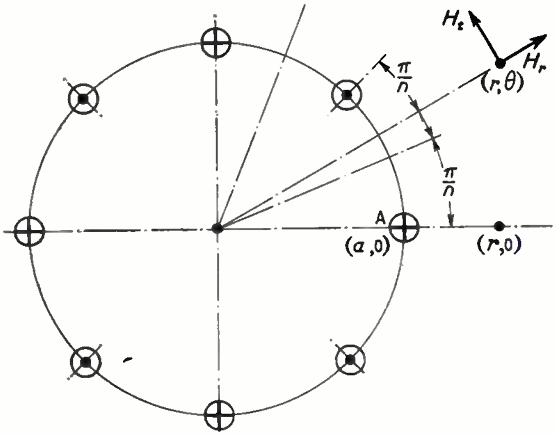


Fig. 1. *Plan of squirrel-cage filament structure.*

Since the point (r, θ) with reference to successive filaments in the anti-clockwise direction becomes

$$r, \left(\frac{2\pi}{n} - \theta\right); \left(r, \frac{4\pi}{n} - \theta\right); \left(r, \frac{6\pi}{n} - \theta\right) \ldots.$$

$$\left\{r, (n-1)\left(\frac{2\pi}{n} - \theta\right)\right\},$$

we have

$$\frac{H_t}{2I} = \frac{a}{r^2}\left[\cos\theta - \cos\left(\frac{2\pi}{n} - \theta\right) + \cos\left(\frac{4\pi}{n} - \theta\right) - \ldots. - \cos\left\{(n-1)\left(\frac{2\pi}{n} - \theta\right)\right\}\right]$$

$$+ \frac{a^2}{r^3}\left[\cos 2\theta - \cos 2\left(\frac{2\pi}{n} - \theta\right) + \ldots. - \cos 2\left\{(n-1)\left(\frac{2\pi}{n} - \theta\right)\right\}\right]$$

$$+ \frac{a^3}{r^4}\left[\cos 3\theta - \cos 3\left(\frac{2\pi}{n} - \theta\right) + \ldots. - \cos 3\left\{(n-1)\left(\frac{2\pi}{n} - \theta\right)\right\}\right]$$

$$+ \ldots., \quad .. \quad .. \quad .. \quad .. \qquad (9)$$

the terms in $1/r$ cancelling out, since there are equal numbers of terms of opposite sign. The above may be abbreviated to

$$H_t = \frac{2I}{r}\sum_{m=1}^{\infty}\left(\frac{a}{r}\right)^m C_{m\theta}, \quad .. \quad .. \qquad (10)$$

$C_{m\theta}$ denoting the sum of the finite cosine series within each term. Similarly we find

$$H_r = \frac{2I}{r}\sum_{m=1}^{\infty}\left(\frac{a}{r}\right)^m S_{m\theta}, \quad .. \quad .. \qquad (11)$$

$S_{m\theta}$ denoting the sum of the corresponding sine series within each term.

Consider the series of sum $C_{m\theta}$. It consists of two parts, each containing $\frac{1}{2}n$ terms of opposite sign; i.e.,

$$\{\cos m\theta + \cos m(\theta - 2\alpha) + \cos m(\theta - 4\alpha) + \ldots.\},$$

and

$$-\{\cos m(\theta - \alpha) + \cos m(\theta - 3\alpha) + \cos m(\theta - 5\alpha) + \ldots.\},$$

where $\alpha = 2\pi/n$, and $(\theta - \alpha)$, $(\theta - 2\alpha)$, …., etc., replace $(\alpha - \theta)$, $(2\alpha - \theta)$, …., etc., without change of sign. The sum to $\frac{1}{2}n$ terms of the positive series is

$$\cos\left\{m\theta - \left(\frac{n}{2} - 1\right)m\alpha\right\}\frac{\sin nm\alpha/2}{\sin m\alpha}, \quad .. \qquad (12)$$

and since $\alpha = 2\pi/n$, $\sin nm\alpha/2 = \sin m\pi$, which is zero for all m. But equation (12) becomes indeterminate when the denominator, $\sin m\alpha = \sin p\pi$, where p is any integer; i.e., when $m =$

$pn/2$. In this case the positive series becomes $\cos m\theta + \cos (m\theta - 2p\pi) + \cos (m\theta - 4p\pi) + \ldots$ to $\frac{1}{2}n$ terms, i.e., $n/2 \cos m\theta = n/2 \cos pn\theta/2$. Similarly the summation for the negative cosine series becomes indeterminate when $m = pn/2$, and the sum is then

$$- \{\cos (m\theta - p\pi) + \cos (m\theta - 3p\pi) + \ldots .\}.$$

When p is an *odd* integer, this becomes

$$- \{ - \cos m\theta - \cos m\theta - \ldots . \text{ to } n/2 \text{ terms}\}$$
$$= \frac{n}{2} \cos m\theta.$$

When p is an *even* integer it becomes $\left(-\frac{n}{2}\cos\frac{pn\theta}{2}\right)$, so that $C_{m\theta} = 0$. Hence $C_m = n \cos \frac{pn\theta}{2}$, where p is *odd*. By the same process we find that $S_{m\theta} = 0$ when p is *even*, and $S_{m\theta} = n \sin pn\theta/2$, where p is *odd*.

Table 1 gives the first three terms in the expansion for H_t.

TABLE 1

n	m	$H_t \Big/ \frac{2In}{r}$
2	1	$\frac{a}{r} \cos \theta + \frac{a^3}{r^3} \cos 3\theta + \frac{a^5}{r^5} \cos 5\theta + \ldots$
4	2	$\frac{a^2}{r^2} \cos 2\theta + \frac{a^6}{r^6} \cos 6\theta + \frac{a^{10}}{r^{10}} \cos 10\theta + \ldots$
6	3	$\frac{a^3}{r^3} \cos 3\theta + \frac{a^9}{r^9} \cos 9\theta + \frac{a^{15}}{r^{15}} \cos 15\theta + \ldots$
8	4	$\frac{a^4}{r^4} \cos 4\theta + \frac{a^{12}}{r^{12}} \cos 12\theta + \frac{a^{20}}{r^{20}} \cos 20\theta + \ldots$
n	$\frac{1}{2}n$	$\left(\frac{a}{r}\right)^{\frac{n}{2}} \cos \frac{n\theta}{2} + \left(\frac{a}{r}\right)^{\frac{3n}{2}} \cos \frac{3n\theta}{2} + \left(\frac{a}{r}\right)^{\frac{5n}{2}} \cos \frac{5n\theta}{2} + \ldots$

The general series may now be summed to infinity since $a/r < 1$. Let $a/r = v$, then if c_n and s_n denote the infinite cosine and sine series, we have

$$c_n + js_n = (vz)^{\frac{n}{2}} + (vz)^{\frac{3n}{2}} + (vz)^{\frac{5n}{2}} + \ldots ,$$

where $z = e^{j\theta}$. The sum to infinity is

$$c_n + js_n = \frac{(vz)^{\frac{n}{2}}}{1 - (vz)^n}.$$

On equating real and imaginary parts, we obtain

$$c_n = \frac{v^{\frac{n}{2}} \cos \frac{n\theta}{2} (1 - v^n)}{1 - 2v^n \cos n\theta + v^{2n}}$$

and

$$s_n = \frac{v^{\frac{n}{2}} \sin \frac{n\theta}{2} (1 + v^n)}{1 - 2v^n \cos n\theta + v^{2n}},$$

whence

$$H_t = \frac{2In}{r} \frac{\left(\frac{a}{r}\right)^{\frac{n}{2}} \cos \frac{n\theta}{2} \left\{1 - \left(\frac{a}{r}\right)^n\right\}}{1 - 2\left(\frac{a}{r}\right)^n \cos n\theta + \left(\frac{a}{r}\right)^{2n}} \quad \ldots \quad \ldots \quad \ldots \quad (13)$$

and

$$H_r = \frac{2In}{r} \frac{\left(\frac{a}{r}\right)^{\frac{n}{2}} \sin \frac{n\theta}{2} \left\{1 + \left(\frac{a}{r}\right)^n\right\}}{1 - 2\left(\frac{a}{r}\right)^n \cos n\theta + \left(\frac{a}{r}\right)^{2n}}. \quad \ldots \quad \ldots \quad \ldots \quad (14)$$

The resultant magnetic field at (r, θ) is then

$$H = (H_t^2 + H_r^2)^{\frac{1}{2}}$$

$$= \frac{2In}{r} \frac{\left(\frac{a}{r}\right)^{\frac{n}{2}}}{\left\{1 - 2\left(\frac{a}{r}\right)^n \cos n\theta + \left(\frac{a}{r}\right)^{2n}\right\}^{\frac{1}{2}}}, \quad \ldots \quad \ldots \quad \ldots \quad (15)$$

and the direction of the resultant field with reference to the radial direction at θ, is

$$\phi = \tan^{-1} \frac{H_t}{H_r} = \tan^{-1} \left\{ \frac{1 - \left(\frac{a}{r}\right)^n}{1 + \left(\frac{a}{r}\right)^n} \cot \tfrac{1}{2}n\theta \right\} \quad \ldots \quad \ldots \quad \ldots \quad (16)$$

It is easily shown that H has equal maxima given by

$$H_{\max} = \frac{2In}{r} \frac{\left(\frac{a}{r}\right)^{\frac{n}{2}}}{1 - \left(\frac{a}{r}\right)^n} \quad \ldots \quad \ldots \quad (17)$$

at $\theta = 0, \frac{2\pi}{n}, \frac{4\pi}{n}, \ldots \ldots$, etc., where the field is wholly tangential, and equal minima given by

$$H_{\min} = \frac{2In}{r} \frac{\left(\frac{a}{r}\right)^{\frac{n}{2}}}{1 + \left(\frac{a}{r}\right)^n}, \ldots \quad \ldots \quad \ldots \quad (18)$$

at $\theta = \frac{\pi}{n}, \frac{3\pi}{n}, \frac{5\pi}{n}, \ldots \ldots$, etc., where the field is wholly radial.

By obtaining similar expansions for H_t and H_r in powers of r/a, the solutions for $r < a$ (i.e., for a point within the squirrel cage) reduce to the form of those already deduced, r/a being substituted for a/r wherever it occurs. In all cases except that for $n = 2$, there is a null point at the centre.

The summation of the series for H_t and H_r, and the comparative simplicity of the resulting expressions, allows computation to be carried out easily. The values of H have been computed for the cases $n = 4$, 8 and 16, and are given in Table 2 in the form

$$\frac{H}{2In/r} = \frac{\left(\dfrac{a}{r}\right)^{\frac{n}{2}}}{\left\{1 - 2\left(\dfrac{a}{r}\right)^{n} \cos n\theta + \left(\dfrac{a}{r}\right)^{2n}\right\}^{\frac{1}{2}}}$$

TABLE 2

Computed values of $H\Big/\dfrac{2In}{r}$

$n\theta =$		0	$\pi/4$	$\pi/2$	$3\pi/4$	π
$n = 4$						
$a/r =$	0·95	4·865	1·262	0·700	0·538	0·497
	0·90	2·355	1·143	0·677	0·527	0·489
	0·80	1·084	0·834	0·592	0·452	0·427
	0·75	0·823	0·696	0·536	0·452	0·427
	0·50	0·267	0·261	0·250	0·239	0·235
$n = 8$						
$a/r =$	0·95	2·420	1·150	0·679	0·528	0·490
	0·90	1·152	0·864	0·603	0·490	0·459
	0·80	0·492	0·461	0·404	0·364	0·351
	0·75	0·352	0·340	0·315	0·295	0·288
	0·50	0·063	0·063	0·062	0·062	0·062
$n = 16$						
$a/r =$	0·95	1·185	0·878	0·607	0·493	0·461
	0·90	0·528	0·490	0·423	0·378	0·363
	0·80	0·173	0·171	0·168	0·164	0·163
	0·75	0·101	0·101	0·100	0·099	0·099
	0·50	0·004	0·004	0·004	0·004	0·004

for various values of a/r. H is plotted in polar form for these cases in Fig. 2. Since the polar diagrams are all symmetrical, Table 2 is taken as far as $\theta = \pi/n$ only; i.e., to a radius midway between two filament wires.

In the foregoing calculation it is assumed that the length of the squirrel cage is great in comparison with the distance of the point (r, θ) from the structure. In the case of a squirrel cage of finite length, however, this is not quite true and in short-electrode valves will lead to appreciable error quite apart from end effects due to the supports, etc. It is easily shown that for a single finite wire, the ends of which subtend angles α and β at a point outside it with reference to the perpendicular from the point to the wire, the field is

$$H = \frac{I}{r}(\sin\alpha + \sin\beta)$$

If the point is very near one end, then $\alpha = 0$, and $\beta \rightarrow \pi/2$, so that $H \rightarrow I/r$; i.e., half the value of H at the centre for an infinitely-long wire.

In the squirrel cage, α and β must vary round the structure for a point outside it, and the problem becomes very cumbersome. A fair approximation may be had by assuming α and β to be constant and multiplying H by a factor $(\sin\alpha + \sin\beta)$ for the point under consideration, α and β being now subtended by the central axis.

3. Magnetron Effect in a Cylindrical Diode with Squirrel-Cage Filament

The previous calculation of the magnetic-field components may be used to obtain an approximate approach to the mechanism of magnetron effect in a cylindrical diode.

To avoid complication we assume that the electric field is the same as that when the filament is a solid cylinder of the filament pitch-circle diameter. From the viewpoint of the space-

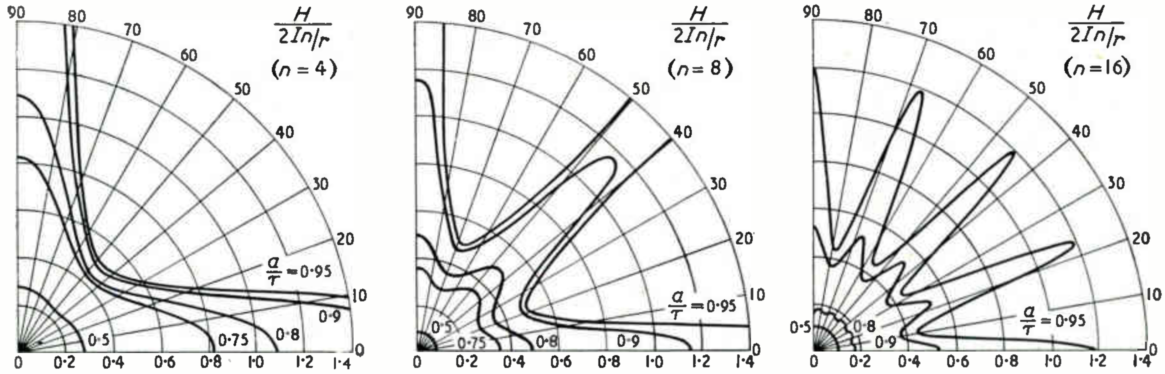


Fig. 2. *The value of H is shown here in polar form for three values of n.*

charge-limited current flow this is approximately true when the number of wires exceeds eight. It is not true when we examine electron trajectories close to individual filament wires. In this region the electric field is small and, due to the initial electron velocities, may be slightly negative. The electric field, however, will not be radial except at points on a wire directly opposite the anode. It will, nevertheless, become sensibly radial within a short distance of each wire, provided the number of wires is not too small. We shall therefore assume the electric field to be wholly radial.

The tangential component of the magnetic field (H_t) due to the filament structure is known. This is a function of both r and θ and is given by equation (13). Let us assume that electrons leave the surface of the structure with zero velocity. Then one electron starting at the point (a, θ) is subjected to the influence of a radial electric field, which is known, and the tangential component of magnetic field.

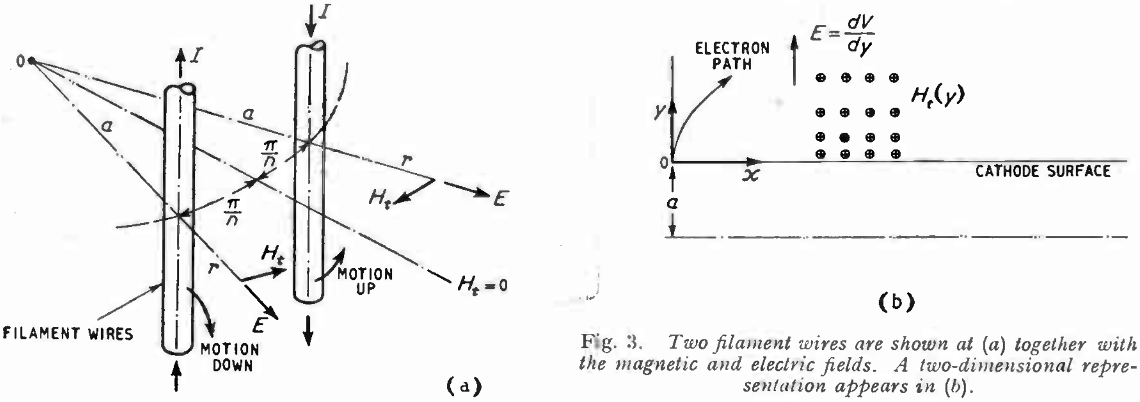


Fig. 3. *Two filament wires are shown at (a) together with the magnetic and electric fields. A two-dimensional representation appears in (b).*

Referring to Fig. 3(a), this shows part of two adjacent filament wires with indication of the heating current I, the electric field E and the tangential magnetic-field component H_t.

With the indicated directions of current and fields, and for $0 \leqslant \theta \leqslant \pi/n$, the electron experiences an upward force, and if H_t were constant with increasing r, the path would be cycloidal provided the electric field were insufficient to deflect the electron into the anode. This is a well-known result.

But when the number of filaments is large, H_t decreases rapidly with increasing r, so that as soon as the electron commences its outward flight it enters a region of decreasing tangential magnetic field and its path is no longer cycloidal.

H_t is maximum at $\theta = 0$ and zero at $\theta = \pi/n$, where the magnetic field is wholly radial. Hence the nature of the 'quasi-cycloidal' path changes between these limits, since the radius of curvature of the trajectory is inversely proportional to H.

At $\theta = \pi/n$, the purely radial magnetic field leaves the normal radial trajectory unaffected under the radial electric field.

When $\pi/n \leqslant \theta \leqslant 2\pi/n$, H_t reverses and the trajectories are directed downwards, having the same path variations between these angular limits. Under a weak electric field, therefore, there are two regions between two adjacent filament wires in which the electrons are travelling in opposite directions, and these directions reverse with the reversal of the heating current. There is a central region at $\theta = \pi/n$ where (ideally) the path is unaffected, and an emitted electron reaches the anode under the influence of the electric field alone. This situation is adequately illustrated by Fig. 3.

Consider now a gradually-increasing electric field due to increasing anode voltage. Electrons at $\theta = \pi/n$ will travel radially outwards as before with increasing acceleration. In the neighbourhood of $\theta = \pi/n$, H_t will be insufficient to prevent capture by the anode, and as E increases, H_t becomes progressively less effective in preventing capture over an ever-increasing zone on either side of $\theta = \pi/n$.

Finally the electrons at $\theta = 0$ and $\theta = 2\pi/n$ are captured for some value of E, this point marking the convergence of the two emission characteristics; i.e., that without and that with magnetron effect.

This mechanism appears to offer a qualitative explanation of the persistence of magnetron effect to quite high values of E and the observed gradual merging of the zero- and full-field emission characteristics. (Section 6.)

4. Approximate Calculation of Magnetron Effect in a Cylindrical Diode

(i) *Constant Potential Gradient.*

In order to determine the point on the emission characteristic where magnetron effect ceases, we must find under what conditions the electrons travelling under the maximum tangential magnetic field just fail to reach the anode.

The maximum value of H_t occurs, as we have shown, at $\theta = 0$, or $2\pi/n$, $4\pi/n$....., etc. Let us now restrict consideration to a diametral plane passing through $\theta = 0$, or $\theta = 2\pi/n$, etc.

The problem may be treated as a two-dimensional one, as shown in Fig. 3(b), since we are considering an electron released in this plane and having a trajectory wholly within the plane. $H_t(r)$ now becomes $H_t(y)$ and is supposed constant along the x-axis. $H_t(\theta)$ need not be considered, since all electrons emitted in other planes have already been captured.

The equations of motion of an electron in this plane are

$$\frac{d^2y}{dt^2} = \frac{e}{m}\frac{dV}{dy} - \frac{e}{m}\frac{H_t(y)}{c} \cdot \frac{dx}{dt}, \quad .. \quad .. \quad (19)$$

$$\frac{d^2x}{dt^2} = \frac{e}{m}\frac{H_t(y)}{c} \cdot \frac{dy}{dt}, \quad .. \quad .. \quad .. \quad (20)$$

where $H_t(y)$ is in e.m.u., and $e/m \; dV/dy$ in e.s.u., and $c = 3 \times 10^{10}$ cm/sec.

As a first approximation we assume the potential gradient to be uniform, so that

$$\frac{dV}{dy} = E,$$

the non-linear gradient in the space-charge condition being treated subsequently.

To simplify the manipulation we use only the first term in the series expansion for H_t, obtained from Table 1. For n wires this is

$$H_t = \frac{2In}{r}\left(\frac{a}{r}\right)^{\frac{n}{2}} = 2Ina^{\frac{n}{2}} r^{-\frac{n}{2}-1}$$

But now $r = y + a$, so that

$$H_t(y) = 2Ina^{\frac{n}{2}}\left(y + a\right)^{-\frac{n}{2}-1}$$

Equations (19) and (20) may then be written

$$\frac{d^2y}{dt^2} = P - Q(y + a)^{-\frac{n}{2}-1}\frac{dx}{dt}, \quad .. \quad (21)$$

$$\frac{d^2x}{dt^2} = Q(y + a)^{-\frac{n}{2}-1}\frac{dy}{dt}, \quad .. \quad .. \quad (22)$$

where $P = \frac{e}{m}E$; $Q = \frac{e}{m}\frac{2I}{c}na^{\frac{n}{2}}$.

On integration of (22) with the initial condition that $dx/dt = 0$ at $y = 0$, we obtain

$$\frac{dx}{dt} = \frac{2Q}{n}\left\{a^{-\frac{n}{2}} - (y + a)^{-\frac{n}{2}}\right\}. \quad .. \quad (23)$$

Substitution of equation (23) in (21) gives

$$\frac{d^2y}{dt^2} = P - \frac{2Q^2}{n}\left\{a^{-\frac{n}{2}}(y + a)^{-\frac{n}{2}-1} - (y + a)^{-n-1}\right\}, \quad .. \quad .. \quad .. \quad (24)$$

which, after integration, and with the initial condition that $dy/dt = 0$ at $y = 0$, becomes

$$\left(\frac{dy}{dt}\right)^2 = 2Py + \frac{8Q^2}{n^2}a^{-\frac{n}{2}}\left(y + a\right)^{-\frac{n}{2}} - \frac{4Q^2}{n^2}\left(y + a\right)^{-n} - \frac{4Q^2}{n^2}a^{-n}, \quad .. \quad (25)$$

whence, taking the positive sign,

$$\frac{dy}{dt} = \frac{2Q}{n}\left\{\frac{Pn^2}{2Q^2}y + 2a^{-\frac{n}{2}}\left(y + a\right)^{-\frac{n}{2}} - \left(y + a\right)^{-n} - a^{-n}\right\}^{\frac{1}{2}} \quad .. \quad .. \quad (26)$$

From equations (23) and (26) we have

$$\frac{dy}{dx} = \left[\frac{Pn^2a^n}{2Q^2} \cdot \frac{y}{\left\{1 - \left(1 + \frac{y}{a}\right)^{-\frac{n}{2}}\right\}^2} - 1\right]^{\frac{1}{2}} \quad .. \quad .. \quad .. \quad (27)$$

This is indeterminate when $y = 0$, since initial conditions prescribe that $dy/dt = dx/dt = 0$ at the origin. Differentiation of numerator and denominator shows that dy/dx is infinite at the origin, which is correct, since an electron must leave the surface normally under the electric field.

Equation (27) does not appear amenable to direct integration but information regarding the upper limit of magnetron effect may be sought by finding the conditions under which $dy/dt = 0$, or what is the same thing, $dy/dx = 0$.

If $dy/dx = 0$, then from equation (27) we have

$$\frac{Pn^2a^n}{2Q^2}y = \left\{1 - \left(1 + \frac{y}{a}\right)^{-\frac{n}{2}}\right\}^2 \quad .. \quad (28)$$

When $y \ll a$, we may expand the binomial on the right, so that $\frac{2Q^2}{Pn^2a^n} = \frac{n^2}{4a^2}y$

$$\text{and } y = \frac{2Pa^{n+2}}{Q^2} = \frac{1}{2}\frac{m}{e}\frac{Ec^2a^2}{I^2n^2} \quad .. \quad .. \quad (29)$$

Converting to practical units, this becomes

$$y = 283\frac{Ea^2}{I^2n^2}\text{ cm.} \quad .. \quad .. \quad .. \quad (30)$$

Thus if the cathode-anode spacing is y cm the cessation of magnetron effect occurs when

$$E = \frac{I^2n^2y}{283a^2}\text{ V/cm} \quad .. \quad .. \quad .. \quad (31)$$

(ii) *Non-Linear Potential Gradient.*

In the space-charge-limited cylindrical diode the current per unit surface area is given by

$$J = \frac{\sqrt{2}}{9\pi}\sqrt{\frac{e}{m}}\frac{V^{\frac{3}{2}}}{(r\beta)^2}\text{ e.s.u.} \quad .. \quad (32)$$

while the corresponding expression for the planar diode is

$$J = \frac{\sqrt{2}}{9\pi}\sqrt{\frac{e}{m}}\,\frac{V^{\frac{3}{2}}}{y^2} \text{ e.s.u.} \quad \ldots \quad \ldots \quad (33)$$

where y is the cathode-anode distance.

In (32) β is Langmuir's well-known tabulated function. When an attempt is made to find the potential gradient in (32), difficulties arise from the function $(r\beta)^2$ and the result cannot be obtained in closed form.

If, however, we are considering an electrode structure in which the ratio of anode to cathode radius approaches unity and both radii are large, there will be no great error in using the planar equation (33) and deriving the potential gradient from

$$V = \left(\frac{9\pi}{\sqrt{2}}\right)^{\frac{2}{3}}\left(\frac{m}{e}\right)^{\frac{1}{3}} J^{\frac{2}{3}}\, y^{\frac{4}{3}}, \quad \ldots \quad \ldots \quad (34)$$

Thus

$$\frac{dV}{dy} = \frac{4}{3}\left(\frac{9\pi}{\sqrt{2}}\right)^{\frac{2}{3}}\left(\frac{m}{e}\right)^{\frac{1}{3}} J^{\frac{2}{3}}\, y^{\frac{1}{3}},$$

$$= kJ^{\frac{2}{3}}\, y^{\frac{1}{3}}, \quad \ldots \quad \ldots \quad \ldots \quad (35)$$

k being substituted for the numerics.

The equations of motion then become

$$\frac{d^2y}{dt^2} = P_1 y^{\frac{1}{3}} - Q(y+a)^{-\frac{n}{2}-1}\frac{dx}{dt}, \quad \ldots \quad (36)$$

$$\frac{d^2x}{dt^2} = Q(y+a)^{-\frac{n}{2}-1}\frac{dy}{dt}, \quad \ldots \quad \ldots \quad (37)$$

where $P_1 = \frac{e}{m} kJ^{\frac{2}{3}}$; $Q = \frac{e}{m}\frac{2I}{c} na^{\frac{n}{2}}$, as before.

The solution of these equations now gives

$$\frac{dy}{dx} = \left[\frac{3}{8}\,\frac{P_1 n^2 a^n}{Q^2}\,\frac{y^{\frac{4}{3}}}{\left\{1-\left(1+\frac{y}{a}\right)^{-\frac{n}{2}}\right\}^2} - 1\right]^{\frac{1}{2}}$$

$$\ldots \quad \ldots \quad \ldots \quad (38)$$

and with the previous approximation, $dy/dx = 0$ when

$$y = 6{\cdot}745\left(\frac{m}{e}\right)^2 \frac{c^3 a^3}{I^3 n^3} J \quad \ldots \quad \ldots \quad (39)$$

and in practical units,

$$y = 1{\cdot}935 \times 10^{9} \frac{a^3}{I^3 n^3} J \text{ cm} \quad \ldots \quad (40)$$

If y is the anode-cathode spacing, J is the current density at which the electron just grazes the anode.

The assumptions made in the above calculation may be recapitulated here:

(i) Electrons are emitted with zero velocity and the trajectories are confined to radial planes. With a Maxwellian velocity distribution this is not true.

(ii) The filament wires are very long. This is justified for points near the centre. Towards the ends, however, the magnetic field decreases. This fact does not affect the upper limit of magnetron effect according to our reasoning, since it means that electrons emitted from the end regions are captured before those emitted from the centre for a given value of E.

(iii) The potential gradient is everywhere radial.

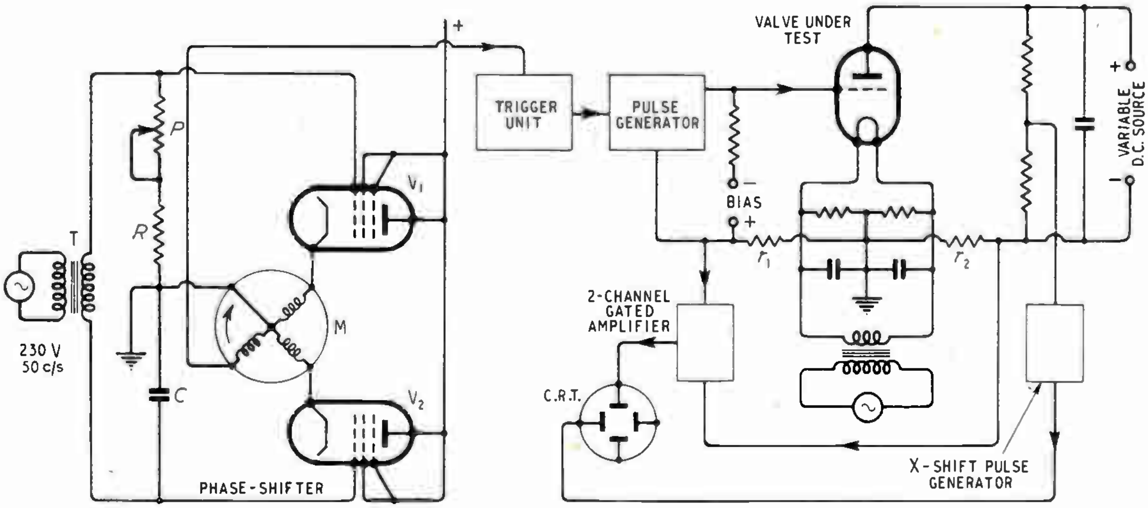


Fig. 4. *Skeleton diagram of test equipment including the phase shifter.*

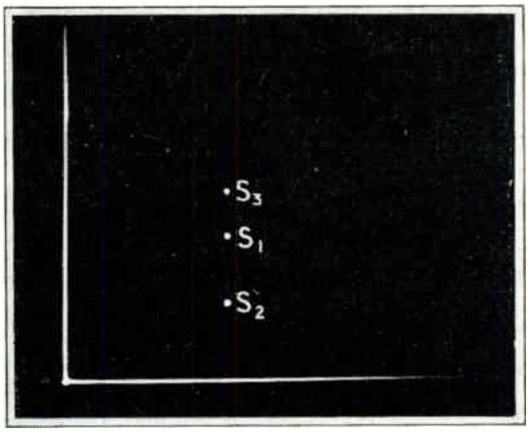


Fig. 5. *Quiescent display. S_1 and S_2 are I_a and I_g levels, S_3 is variable-level calibrating pulse.*

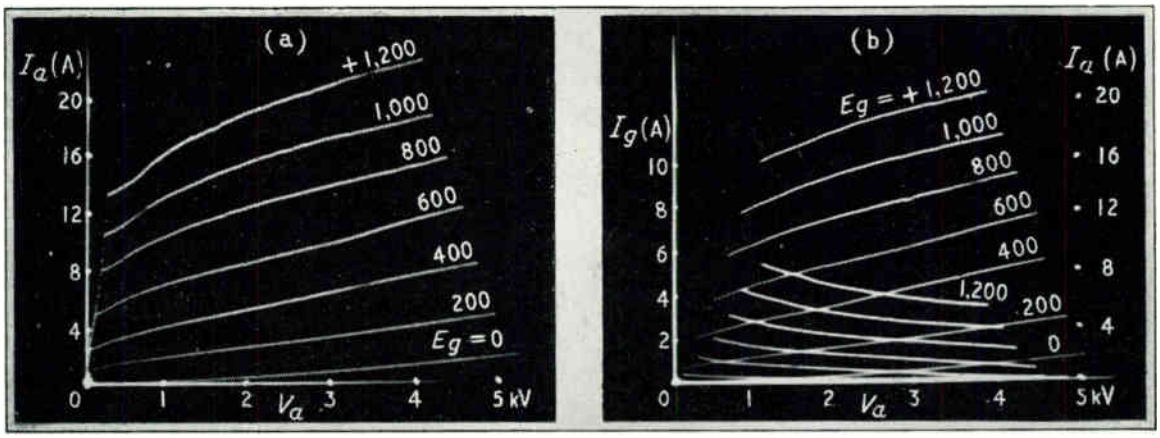


Fig. 6. (*a*) *Recording of I_a characteristics alone. Positive grid* 0 — 1,200 V; (*b*) *recording of simultaneous I_a and I_g characteristics.*

This is approximately true towards the anode. The space-charge-free field can be closely determined by a conformal transformation, but the field with space-charge has so far defied solution in general terms for this electrode configuration.

(iv) The potential gradient approximates to that of a planar diode. This restricts the results to large valves where the inter-electrode spacing is small in comparison with the overall diameter. This has been adopted for mathematical expediency, although conflicting with (iii) above.

5. Recording Equipment

To determine the extent of magnetron effect it is necessary to record the valve characteristics at zero and maximum magnetic field. This may be easily carried out by pulse technique if the recurrence frequency of the pulse generator is synchronized with the frequency of the a.c. filament-heating supply; or if both pulse generator and filament are run from the same supply. Provision must be made for setting the phase of the pulse to any point on the a.c. cycle, and it is important that the instants of zero and maximum be accurately known.

The recording technique for positive-grid characteristics developed by the author and described in a previous paper[2] embodies the necessary phase-shifting equipment. The phase-shifter itself is of the continuously-variable type employing a two-phase magslip. A schematic diagram of the essentials is given in Fig. 4. The 230-V supply is fed via the isolating transformer T to a phase-splitting network consisting of the resistance *R*, potentiometer *P* and capacitance *C*. *P* is used to obtain amplitude balance between the quadrature components of the e.m.f. applied to the grids of V_1 and V_2, which are 10-W pentodes in triode connection.

The two-phase magslip M has one stator winding in each cathode lead, so that a rotating magnetic field is produced. The angular setting of the rotor then determines the phase of the rotor e.m.f. which is subsequently employed to generate trigger pulses.

The advantages of this type of phase-shifter are (a) constant output e.m.f. at all settings provided the quadrature components are initially balanced, and (b) the rotor may be motor-driven to provide recordings of magnetron-modulation waveforms in conjunction with a moving-film oscillograph camera.

The pulse generator is designed to give an approximately rectangular pulse the amplitude of which may be set at any value from 0-2·5 kV by

'Variac' control on the power supply. The width of the pulse top is variable from about 5-150 μsec. During valve conduction the instantaneous grid and anode currents are proportional to the pulse voltages developed across the small 'shunt' resistances r_1 and r_2 which are of the order of 1 ohm.

The signals from r_1 and r_2 are passed through a two-channel amplifier having a common output stage, each channel being normally blocked until opened alternately by electronic switching for a period overlapping the duration of the incoming voltage pulses from r_1 and r_2. The recurrence frequency of either signal (i.e., anode or grid current) is thus 25 c/s, since one channel only is opened every fiftieth of a second.

The valve characteristics are recorded by obtaining a horizontal X-deflecting pulse which is accurately proportional to the anode voltage, or to the grid pulse amplitude, depending on the type of characteristic required. If then the anode voltage is swept through its range by manual or automatic control, and the signals appear as two bright spots on the same abscissa, these will trace out the anode and grid current curves on a base of anode voltage for one value of grid voltage.

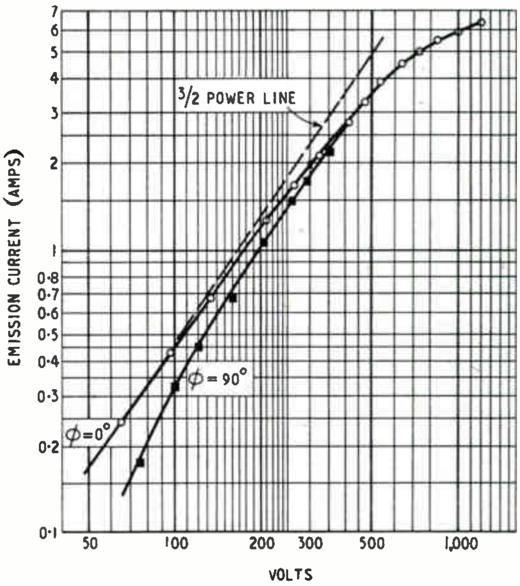


Fig. 8. *Log-log plot of emission characteristic of EH.A 2500 showing divergence due to magnetron effect.*

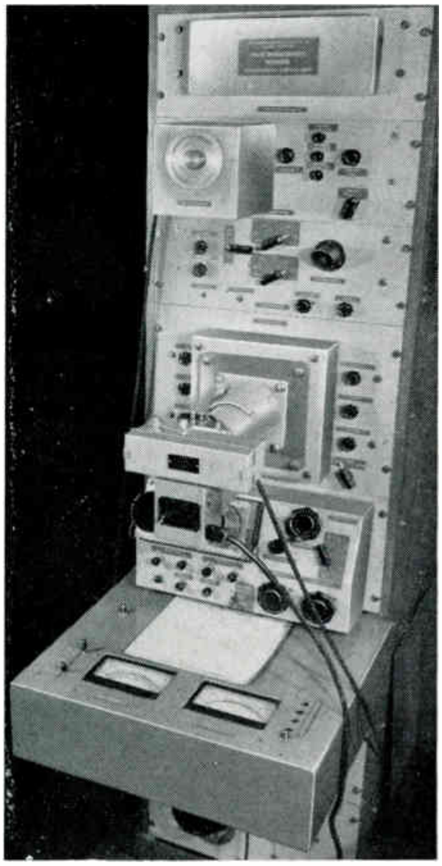


Fig. 7. *Experimental display unit of the valve-characteristic recorder.*

In the quiescent state (anode voltage steady) the display appears as in the oscillogram of Fig. 5. S_1 and S_2 are the bright spots marking the anode- and grid-current levels, while S_3 is the level of a variable calibrating pulse of known amplitude. S_3 can be made to lie on S_1 or S_2 by manual control and the current values found by a simple calculation. Alternatively, in a photographic recording of characteristics, such as Fig. 6, S_3 may be used to superimpose current and voltage markers. The co-ordinate axes are 'drawn' electronically. The display will not be further discussed here.

With this equipment it is possible to examine magnetron effect on the whole characteristic, or at any desired level of anode and grid current. By driving the phase-shifter at constant speed and using a film drive the waveform of the magnetron modulation may be examined at any current level.

It is important when recording magnetron effect that all other sources of modulation be eliminated from the system. Internal 50-c/s 'hum' is detected by substituting a resistance load for the valve under test and noting whether the signal spots remain absolutely steady as the phase-shifter is rotated. The filament of the valve under test must be connected symmetrically to the filament transformer as shown in Fig. 4, for if one side is earthed, the electrode current levels depend on the phase of the pulse with respect to that of the filament supply. The recording equipment is shown in Fig. 7.

6. Experimental Results for Diode Case

In order to test the validity of the theory advanced in Section 4, two valves were tested. These were both of the short-electrode type designed for very short-wave service and violated some of the fundamental assumptions on which the theory was based. Long-electrode valves (such as the CAT 14) were not available at the time these experiments were made. The leading figures are given in Table 3.

In each case the anode was earthed and the pulse applied to the grid, so that all electrons were trapped by the grid. This simulates the diode condition first discussed.

(i) *20-kW Triode.*

Magnetron effect ceased in the region of 1·26 A emission. The precise point of cessation was difficult to determine owing to the gradual convergence of the zero- and full-field characteristics.

From equation (40), with $J = 1{\cdot}26/115 = 0{\cdot}0109$,

$$y = \frac{1{\cdot}935 \times 10^9 \times (2{\cdot}11)^3 \times 0{\cdot}0109}{41^3 \times 16^3} = 0{\cdot}72 \text{ cm.}$$

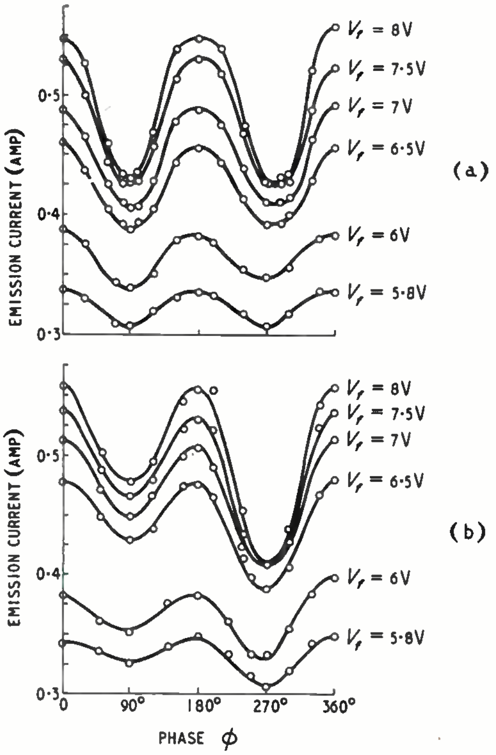


Fig. 9. *'Magnetron' modulation of emission of EHA 2500 with grid and anode strapped at V = 120 V; (a) is for symmetric and (b) for asymmetric filament connection.*

The actual value of y is 0·49 cm; i.e., the filament-grid spacing. The experimental result is thus 2·3 mm too great. This is a somewhat large percentage error, but when consideration is given to the approximations involved and the short length of the electrode structure, it would appear that the theory of the mechanism of magnetron effect is probably broadly fulfilled.

TABLE 3

	20 kW Triode	5 kW Triode
Grid rad. $(y + a)$	2·6 cm	0·86 cm
Fil. P-C rad. (a)	2·11	0·5
No. of fils. (n)	16	4
Fil. current (per cond.)	41 A	40·85 A
Approx. active area of grid cylinder	115 cm²	35 cm²
Approx. active area of anode cylinder	360 cm²	76 cm²

(ii) *5-kW Triode.*

Magnetron effect ceased in the region of 0·70 A. We now find $y = 0{\cdot}9$ cm, the actual value of y being 0·365 cm. A greater divergence is to be expected in this case owing to greater violation of the initial assumptions.

(iii) *Magnetron Effect on the Emission Characteristics with Grid and Anode Strapped. Valve Type EHA*2500.

Fig. 8 shows a logarithmic plot of the emission characteristics of the EHA2500 triode at the zero- and full-field condition with grid and anode strapped together. This again is a 'short' valve having a pure tungsten filament and saturation sets in early due to the end-cooling of the filament by the supports. It will be noted that in this case magnetron effect persists up to about 3·5 A total emission.

(iv) *Magnetron Modulation Waveforms with Grid and Anode Strapped. Valve Type EHA*2500.

(a) *With Symmetric Filament Connection.*

The waveform of the modulation caused by magnetron effect was determined by maintaining fixed pulse amplitude and taking readings of emission current at 10° phase intervals, these experiments being carried out prior to the fitting of the motor drives on phase-shifter and oscillograph camera. The waveforms obtained are shown in Fig. 9(a) at various filament voltages. The filament voltage was progressively reduced in order to find whether there was any significant change of waveform approaching saturation with the pulse amplitude maintained constant.

(b) *With Asymmetric Filament Connection.*

Fig. 9(b) exhibits the change in waveform due to asymmetric filament connection (one side earthed). An estimation of the magnitude of the additional modulation due to this cause may be obtained by integrating the emission along the length of the filament, assuming the 3/2 power law to hold, and the filament voltage to vary linearly along its length. This calculation is carried out in the Appendix.

7. Experimental Results for Triode Type EHA2500

If grid and anode currents are measured separately with $V_a = V_g$, it is found that (i) the anode current, I_a, is subject to magnetron effect, and (ii) magnetron effect ceases at approximately the same value of potential on both I_a and I_g characteristics, and (iii) the I_g characteristic exhibits a 'reversed' magnetron effect; i.e., there is a net increase of I_g, although a net loss exists in $(I_a + I_g)$ under these conditions. At other potential ratios there may be a net gain or a net loss in I_g in the full-field condition as shown below.

The fact that I_a exhibits magnetron effect could mean either that the effect is controlled by the grid, or that electrons are passing the grid mesh and just grazing the anode, or both. Taken in conjunction with the fact that magnetron effect appears to cease at about the same potential on grid and anode, however, the inference is that if $V_a = V_g$, I_a is affected indirectly by magnetron effect at the grid, so that cessation at the grid implies cessation at the anode.

The modulation waveforms obtained with V_a/V_g varying are given in Fig. 10. A qualitative explanation of these is now offered. A certain degree of asymmetry will be observed in the waveforms, more particularly in the I_g waveforms of Fig. 10(b) and Fig. 12(b). This is due to slight changes of filament temperature caused by varying filament-supply voltage, which was manually controlled during these experiments. All the waveforms should, of course, repeat every 180°.

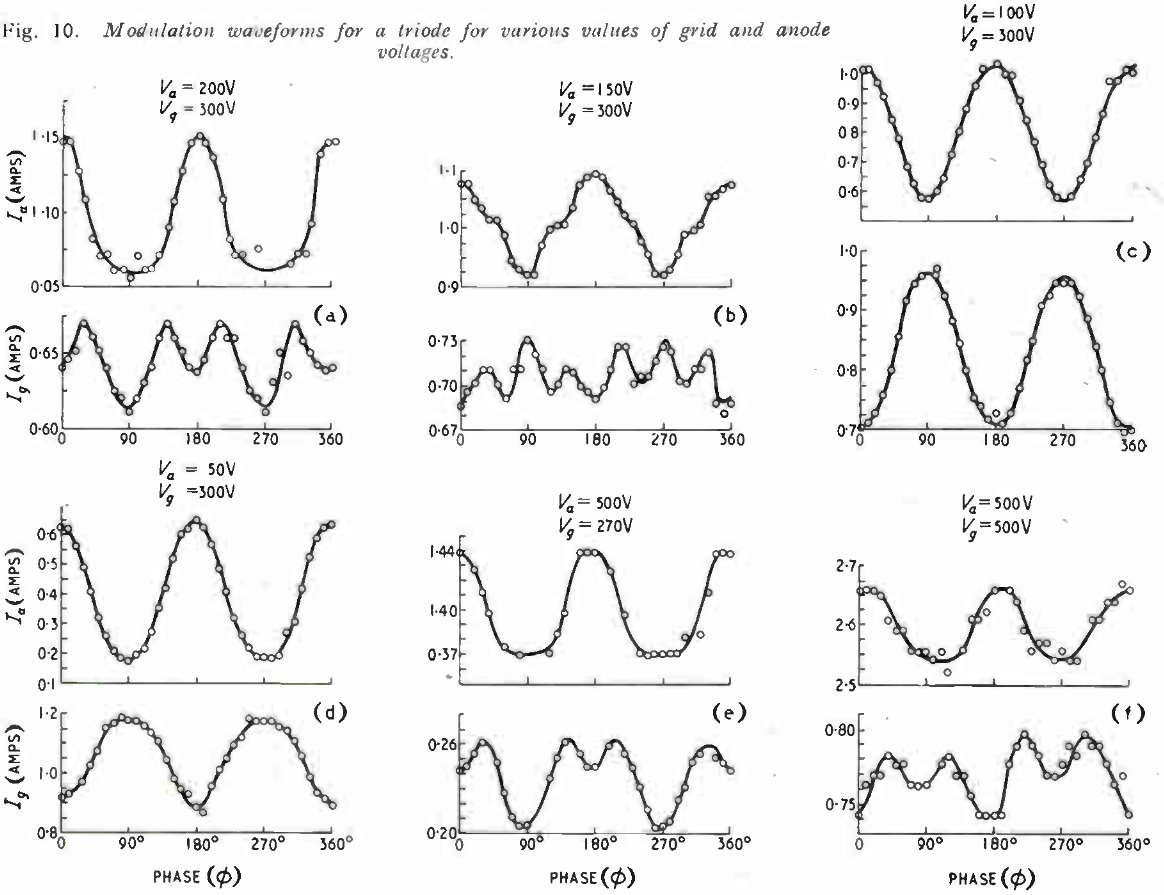
Analysis of Waveforms, Fig. 10.

(a) $V_a = 200\text{ V}$, $V_g = 300\text{ V}$.

At $0 \leqslant \phi \leqslant 30°$. Increasing H at first causes increase of I_g and decrease of I_a at the same rate.

At $30° \leqslant \phi \leqslant 90°$. Increasing H now robs

Fig. 10. *Modulation waveforms for a triode for various values of grid and anode voltages.*



both grid and anode, so that I_a and I_g fall together until $\phi = 90°$. The reverse process occurs during the next quarter cycle.

(b) $V_a = 150$ V, $V_g = 300$ V.

At $0 \leqslant \phi \leqslant 30°$. Increasing H again causes equal and opposite changes of I_a and I_g as in (a). Since V_a is reduced in this case, however, and I_g greater, the changes beyond this region are different.

At $30° \leqslant \phi \leqslant 90°$. At $\phi = 30°$, increasing H

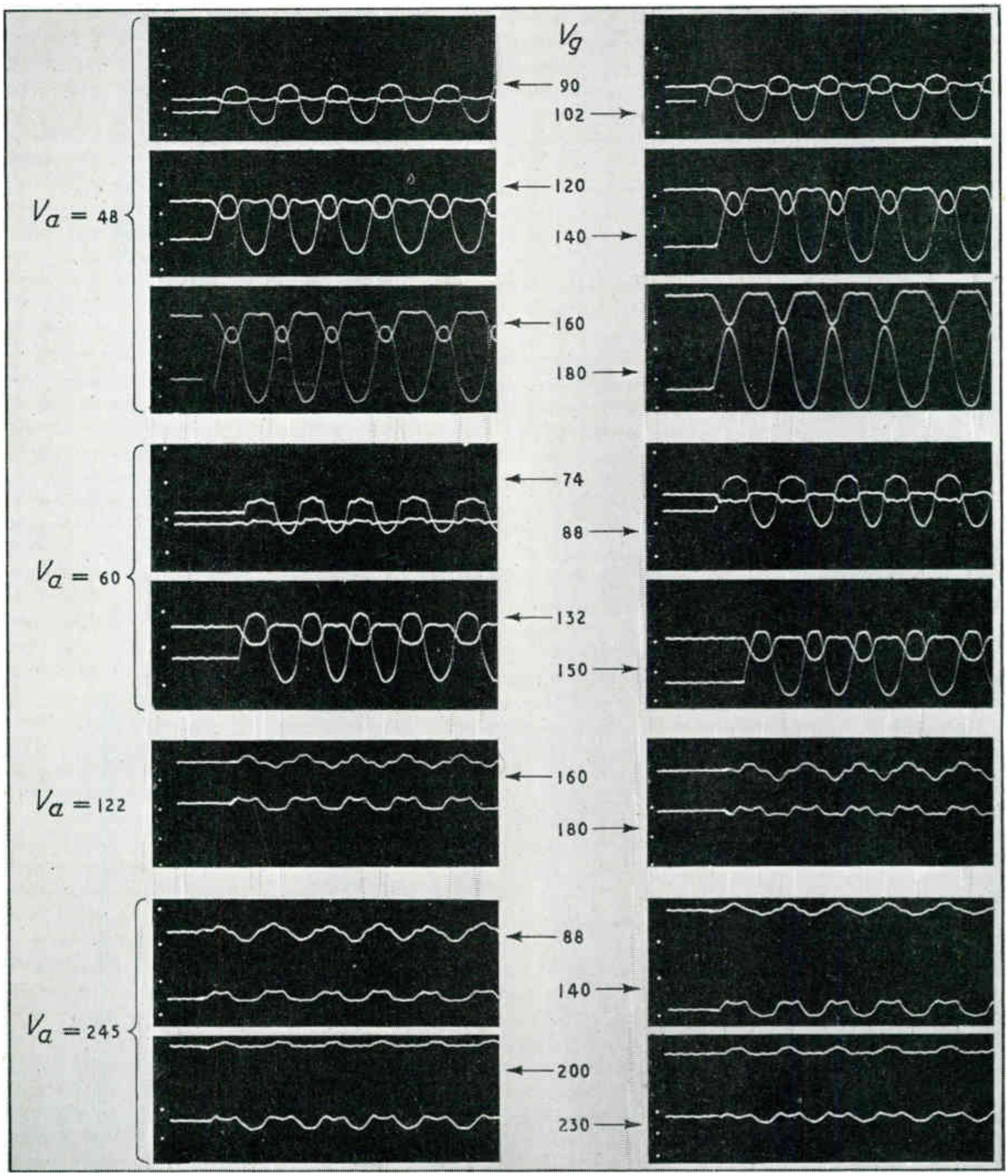


Fig. 11. *Photographic recording of modulation waveforms for a triode. Calibration marks are at 0·125 A intervals*

overcomes the rising tendency of I_g and results in a temporary arrest in the fall of I_a. This is visible as a point of inflection on the falling I_a curve.

At $\phi = 60°$, I_a and I_g have both decreased by different amounts as in (a). Beyond $\phi = 60°$, and despite increasing H, I_g now rises due to current transferred from I_a. This process results in the triple-peaked waveform of I_g.

(c) $V_a = 100$ V, $V_g = 300$ V.

Here the steady fall of I_a caused by rising H is transferred to the grid and completely masks the former tendency of I_g to fall in the region of $\phi = 60°$ as in (a) and (b).

Magnetron effect thus results in a net gain of I_g at $\phi = 90°$ as in (b). The 'anti-phase' relationship of I_a and I_g is most striking.

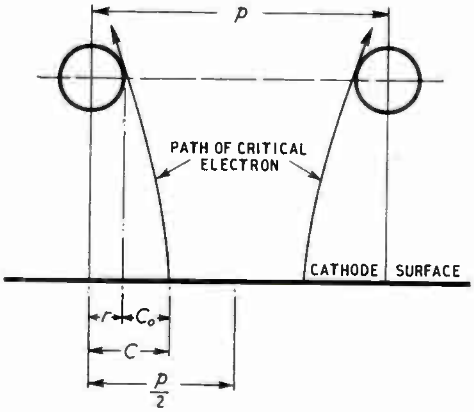


Fig. 12. *The critical electron.*

(d) $V_a = 50$ V, $V_g = 300$ V.

The 'anti-phase' relationship of I_a and I_g is maintained, but the modulation amplitude has increased.

(e) $V_a = 500$ V, $V_g = 270$ V.

The shape of the curves is similar to (a) although $V_a > V_g$ in this case. The mechanism is the same.

(f) $V_a = 500$ V, $V_g = 500$ V.

There is a net gain of I_g due to magnetron effect. The mechanism is similar to (a) and (e), but the fall of I_g towards $\phi = 90°$ is decreased owing to the greater control of the grid over the effect of increasing H.

Photographic Recording of Waveforms

In a later series of experiments photographic recording was employed. The phase-shifter was driven at 4·5 r.p.m. by a small motor, while the film drive speed was 0·04 in/sec.

Some of the recordings are shown in Fig. 11 and exhibit waveforms similar to those previously obtained by more laborious point-by-point work.

8. Discussion

The theory advanced in Sections 3 and 4 is doubtless over-simplified, perhaps even somewhat naive, but as far as the author can judge, the calculation becomes quite preposterous unless drastic simplifying assumptions are made, and indeed, the end scarcely justifies the labour involved in the attempt.

It is perhaps helpful to consider magnetron effect as equivalent to a decrease of grid pitch with a spiral grid. When $V_a = V_g$, the ratio of anode to grid current, $I_a/I_g = \delta$, the true current division ratio. This follows from the semi-empirical law of Tank and Lange:

$$\frac{I_a}{I_g} = \delta\left(\frac{V_a}{V_g}\right)^{\frac{1}{2}}, \text{ for } \frac{V_a}{V_g} > 0{\cdot}8,$$

when secondary emission is small.

As pointed out by Spangenberg,[3] δ is ultimately determined by the starting point on the cathode surface of an electron which just grazes the nearest grid wire. This he terms the 'critical electron'. Fig. 12 shows that

$$\delta = \left(\frac{I_a}{I_g}\right)_{v_a = v_g} = \frac{p/2 - c}{c}$$

Spangenberg then derives an expression for $(c - r) = c_0$ in terms of the electrode geometry for the condition $V_a = V_g$. His solution takes no account of space-charge. He enunciates the useful concept of 'effective grid radius' which is $r' = r + c_0$. If we now consider the action of a superimposed magnetic field, H_t, we are led immediately to an apparent alteration in the starting point of the critical electron, and with $V_a = V_g$, an increase in the effective grid radius, due to the modified trajectory. Regarded from another viewpoint: in the absence of H_t the average trajectory is normal to the grid cylinder except very near the wires. In the presence of H_t the average trajectory meets the grid cylinder obliquely, so that the effective grid pitch is decreased, i.e., the effective grid wire radius is increased. As the potential gradient increases, the obliquity decreases and finally becomes negligible at the grid. Magnetron effect then ceases at both grid and anode. This view is supported by the fact that there is a net gain of I_g at $\phi = 90°$ when $V_a = V_g$.

9. Acknowledgments

The work was carried out in the Research Department of Metropolitan-Vickers Electrical Co., Ltd., Trafford Park, Manchester.

Grateful acknowledgment is made to Dr. C. Dannatt, O.B.E., D.Sc., Director of Research, and to Mr. B. G. Churcher, M.Sc., M.I.E.E., Manager of Research Department, for permission to publish this paper.

APPENDIX

Magnetron Modulation with Asymmetric Filament Connection.

Let the emission equation with symmetrical connection be $I = kV_a^{3/2}$ .. .. .. (1)

where k is a constant.

If there is no saturation anywhere, the emission per unit length is then $kVa^{3/2}/l_f$, where l_f is the total filament length. If one end of the filament is now earthed, the voltage distribution is linear and is given by

$$v(x) = V_f(x/l_f) \sin \omega t \quad .. \quad .. \quad .. \quad .. \qquad (2)$$

where $V_f \sin \omega t$ is the alternating filament voltage. In terms of the phase-shifter setting, ϕ, this is

$$v(x) = V_f(x/l_f) \sin \phi \quad .. \quad .. \quad .. \quad .. \qquad (3)$$

since we are examining conditions with ϕ constant at any one setting.

The emission equation may now be written in differential form as

$$dI = \frac{k}{l_f}\left(V_a + V_f \frac{x}{l_f} \sin \phi\right)^{\frac{3}{2}} dx \quad .. \quad .. \qquad (4)$$

whence

$$I = \frac{k}{l_f} V_a^{\frac{3}{2}} \int_0^{l_f} \left(1 + \frac{V_f}{V_a}\frac{x}{l_f} \sin \phi\right)^{\frac{3}{2}} dx \quad .. \qquad (5)$$

Since $\frac{V_f}{V_a} \cdot \frac{x}{l_f} < 1$, the integrand may be expanded. On integration we obtain

$$I = kV_a^{\frac{3}{2}} \left\{1 + \frac{3}{4}\frac{V_f}{V_a} \sin \phi + \frac{3}{24}\left(\frac{V_f}{V_a}\right)^2 \sin^2 \phi - \frac{3}{192}\left(\frac{V_f}{V_a}\right)^3 \sin^3 \phi + \dots\right\} \quad .. \quad .. \qquad (6)$$

At $\phi = 90°$, equation (6) becomes

$$I = kV_a^{\frac{3}{2}} \left\{1 + \frac{3}{4}\frac{V_f}{V_a} + \frac{3}{24}\left(\frac{V_f}{V_a}\right)^2 - \dots\right\} .. \qquad (7)$$

From the emission characteristic below saturation at $\phi = 0$, we find $k = 0{\cdot}408 \times 10^{-3}$. In Fig. 9(a) all curves are taken at $V_a = 120$ V and the estimated emission at $\phi = 0$ is thus $I = 0{\cdot}408 \times 10^{-3} \times 120^{3/2} = 0{\cdot}54$ A. This figure should also be the value at $\phi = 0$ in Fig. 9(b) for the $V_f = 8$ V curve. The values at the experimental points are actually 0·547 A and 0·557 A.

At $\phi = 90°$ the additional modulation due to V_f should counteract the decrease of emission due to magnetron effect by the difference between equations (7) and (1) (i.e., by the peak value of the modulation component I_m) so that

$$I_m = kV_a^{3/2} \left\{\frac{3}{4}\left(\frac{V_f}{V_a}\right) + \frac{3}{24}\left(\frac{V_f}{V_a}\right)^2 - \dots\right\} .. \qquad (8)$$

On substitution of $V_f = 8\sqrt{2} = 11{\cdot}31$, $k = 0{\cdot}408 \times 10^{-3}$, and $V_a = 120$, equation (8) becomes

$$I_m = 0{\cdot}54 \left\{\frac{3}{4}(0{\cdot}085) + \frac{3}{24}(0{\cdot}085)^2 - \frac{3}{192}(0{\cdot}085)^3 + \dots\right\} = 0{\cdot}035 \text{ A.}$$

The peak to trough amplitude in Fig. 9(a) at $\phi = 90°$ is found to be 0·1175 A, while that of Fig. 9(b) is 0·0825 A. The difference between these values gives $I_m = 0{\cdot}035$ A, which agrees with the estimated figure.

At $\phi = 270°$, equation (8) becomes

$$I_m = kV_a^{\frac{3}{2}} \left\{\frac{3}{4}\left(\frac{V_f}{V_a}\right) - \frac{3}{24}\left(\frac{V_f}{V_a}\right)^2 \frac{3}{192} - \left(\frac{V_f}{V_a}\right)^3 - \dots\right\} \quad .. \quad .. \quad .. \qquad (9)$$

$= 0{\cdot}034$ A, on numerical substitution.

The difference between the corresponding values of peak to trough gives $I_m = 0{\cdot}029$ A, which is still in fair agreement with the estimated figure.

REFERENCES

[1] Bell, J., Davies, J. W., Gossling, B. S., *J. Instn Elect. Engrs*, Vol. 83, p. 176, 1938.

[2] Hardie, A. M., *Metropolitan Vickers Gaz.*, Vol. 23, p. 350, 1951.

[3] Spangenberg, K. R., *Proc. Inst. Radio Engrs*, Vol. 28, p. 226, 1940

RIVLIN INSTRUMENTS

An error occurred in this firm's advertisement in the August issue. The input impedance of the valve voltmeter Model VV.1 was given as 40 megohms instead of 20 megohms.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Values for July 1952

Date 1952 July	Frequency deviation from nominal: parts in 10^8		Lead of MSF impulses on GBR 1000 G.M.T. time signal in milliseconds
	MSF 60 kc/s 1029-1130 G.M.T.	Droitwich 200 kc/s 1030 G.M.T.	
1	+ 0·9	− 1	− 34·4
2	+ 0·9	− 1	− 33·7
3	+ 1·1	− 1	− 32·4
4	+ 1·2	− 1	− 31·1
5	+ 1·1	− 1	− 30·4
6	+ 1·2	− 1	− 29·8
7	+ 1·2	− 1	− 28·6
8	+ 1·2	0	− 28·0
9	+ 1·2	− 1	− 25·6
10	+ 1·2	0	− 25·2
11	− 0·9	0	− 24·2
12	− 0·8	+ 1	− 27·0
13	− 0·7	+ 1	− 27·2
14	− 0·7	+ 1	− 29·0
15	− 0·7	+ 2	− 28·7
16	− 0·7	+ 2	− 28·3
17	− 0·6	+ 1	− 31·4
18	− 0·6	+ 1	− 31·0
19	− 0·5	+ 1	− 32·6
20	− 0·5	+ 1	N.M.
21	− 0·5	0	− 35·1
22	− 0·5	+ 1	− 35·7
23	− 0·4	+ 1	− 35·8
24	− 0·4	+ 1	− 37·2
25	− 0·3	+ 1	− 38·1
26	− 0·3	0	− 41·7
27	− 0·3	+ 2	− 40·9
28	− 0·3	+ 2	− 41·4
29	− 0·2	+ 2	− 43·4
30	− 0·2	+ 2	− 44·0
31	− 0·2	+ 2	− 44·3

The values were estimated on 1st August 1952.

The transmitter employed for the 60-kc/s signal is sometimes required for another service.

NM. = Not measured

SECONDARY-EMISSION VALVES*

Properties with Magnesium Oxide Targets

By Masaki Hirashima

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SUMMARY.—Owing to the peculiar properties of magnesium oxide secondary-electron emitters, which were thoroughly investigated by Kawamura in Japan, potentials of from 10 to 100 V are generated on the surface of such emitters. These potentials govern the secondary-electron yield, giving large values of yield compared with that at zero voltage. This results in a marked degree of distortion in the waveform of secondary-electron currents in the case of the amplification of a single pulse or pulses of very low recurrence frequency, but only a slight amount in the case of the amplification of pulses of high recurrence frequency. The general trend of the waveform distortions is illustrated graphically by means of semi-quantitative analysis of the experimental data obtained by Kawamura, assuming that the after-effect characteristic of Malter effect does not manifest itself at all in the present case. It is also deduced that if the Malter effect should appear in the secondary-emission phenomena in question, a drastic decrease in mutual conductance would be observed with secondary-emission valves of conventional type.

1. Introduction

WHEN secondary-emission valves were described for the first time in 1938,[1] MgO was used as the emitter material, but because of difficulties in its treatment, or for other reasons, the valves failed to find general acceptance. Thereafter, various secondary-emitter materials were tried and many emitters have been proved usable for practical purposes, among which BaO-SrO deposited on a nickel-base metal by cataphoresis,[2] Cu-Be alloys,[3] and Ag-Mg or Cu-Mg alloys[4,5] were considered to be most excellent.

Among these, MgO has undoubtedly the most peculiar properties, which were studied very thoroughly by Kawamura in our laboratory in 1942.[6] It is almost certain that such an emitter as BeO owes its large secondary yield to the same emission mechanism as MgO, which seems to have no small effect upon the performance of secondary-emission valves at moderately high frequencies. When the present writer was engaged in developmental work on B-K tubes incorporating secondary-emission multipliers during the last war, working with wavelengths of about 50 cm, his results led him to suppose that the gain of secondary-emission multipliers might be smaller in the u.h.f. regions than was indicated by static measurements.[7] It is the object of this paper to consider this matter somewhat more quantitatively, taking advantage of the experimental data obtained previously by Kawamura.

2. Peculiar Properties of MgO Secondary Emitters

According to Kawamura, secondary emitters made of MgO have the following three peculiar properties in contrast to pure metals: (1) the collector characteristics (collector-current–collector-voltage characteristics with the target voltage kept constant) show saturation at very high collector voltages; (2) the yield (δ) (i.e., the ratio of the secondary to the primary currents) decreases on raising the temperature of the target (secondary emitter); (3) the yield (δ) is a function of the primary-electron current i_p; i.e., the increase in the primary current results in an increase in the yield.

These properties may be explained very satisfactorily by assuming that the positive charge produced on the surface of the MgO target by liberation of secondary electrons gives rise to a very strong electric field within the layer of MgO tending to pull out of the layer the secondary electrons produced at various depths. By the method of inverse field Kawamura measured the surface voltage thus produced on the target surface, and found that this voltage lay in the range of 10 to 100 V or more, producing a very strong field of the order of 10^6V/cm. Some of his results are reproduced in Figs. 1 and 2. Fig. 1 shows the relation between the surface voltage produced on a MgO target and the current flowing through the layer, $i_p\ (\delta - 1)$, the conductivity of the target being taken as a parameter. The conductivity of the layer was varied by first sputtering Mg metal on the target surface and then subjecting it to heat treatment, the measurement of the yield being conducted at room temperature at $V_p = 800$ V and $i_p = 100\,\mu$A. These curves satisfy Poole's law,[8] which holds good for the current flowing through a semiconducting layer under the influence of a strong electric field:

$$i = A \exp (Bv) \quad .. \quad .. \quad .. \quad .. \quad (1)$$

where A and B are material constants and v is the voltage across the layer in volts. It is clearly seen in this figure that the yield decreases on increasing the conductivity of the layer. Next, the stronger the field intensity F within the layer, the larger the yield, as shown in Fig. 2, in which the full

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curve represents the following theoretical expression derived by Kawamura:

$$\delta = \frac{n}{2}\left(1 - \sqrt{\frac{W - Fd}{E}}\right) \quad .. \quad .. \quad (2)$$

where W and F are the inner potential of MgO and the field intensity within the layer respectively. Furthermore, it was assumed in deriving the above expression that a single primary electron could produce n secondary electrons having the energy of E eV at the depth of d cm from the surface of the layer, and in the present case they were taken as $n = 40$, $W = 10$ eV, $d = 1{\cdot}65 \times 10^{-6}$ cm, and $E = 14{\cdot}7$ eV so as to make it agree as nearly as possible with the experimental data shown in the figure. It seems to be remarkable that the yield at zero field intensity, $F = 0$, is as low as about 3·4.

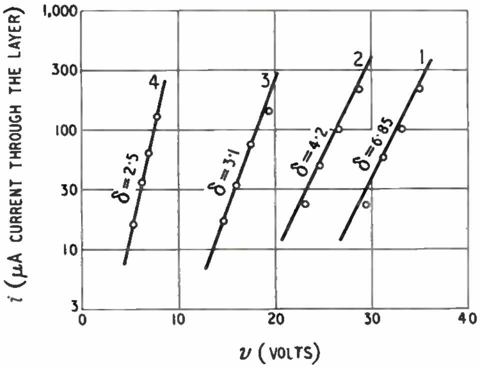

Fig. 1. *Relationship between the current through the layer and the voltage across the layer, the conductance of the layer being taken as a parameter; δ measured at room temperature at V_p = 800 V and I_p = 100 μA (Kawamura).*

These peculiar properties of MgO used as secondary emitters remind us of those of thin-film field emission known as Malter effect.[9] Malter electrons are, however, not secondary electrons in the literal sense of the words. In contrast to Malter effect, it is said that the secondary electrons extracted through the strong electric field from within the MgO layer are not those produced by field emission but those actually produced by primary impact, the strong field within the layer simply extracting the secondary electrons already produced there. The instant the primary electron current is cut off, therefore, the secondary-electron current may cease to flow, thus producing no after-effect.

The empirical formula of the conductance of MgO may be derived from Kawamura's data (for example, curve 1 of Fig. 1):

$$i = 8{\cdot}44 \times 10^{-10} \exp\,(0{\cdot}354\, v) \quad .. \quad (3)$$

$$\text{from which } di/dv = a = 0{\cdot}354\, i \quad .. \quad (4)$$

where a is the conductance in mhos and i is the current through the layer in amperes. From Equ. (4) it is seen that the resistance of the MgO layer is equal to about 28 kΩ at $i = 100\,\mu$A. We shall hereafter confine our considerations mainly to the emitter corresponding to curve 1 of Fig. 1.

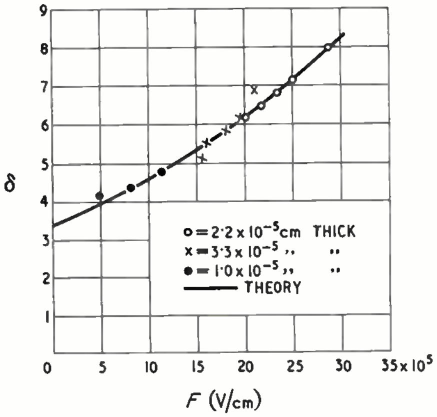

Fig. 2. *Dependence of the yield upon the field intensity within the layer; δ measured at room temperature at V_p = 800 V and I_p = 100 μA (Kawamura).*

3. Build-up and Decay of the Voltage produced on the Surface Layer of MgO

A secondary emitter made of MgO possessing the above-mentioned properties may well be represented by an equivalent circuit, as shown in Fig. 3, in which C denotes the capacitance between the surface layer and the base metal made of nickel, and R the non-linear resistance of the semi-conducting layer of MgO as governed by Poole's law, being a function of the current flowing through the layer.

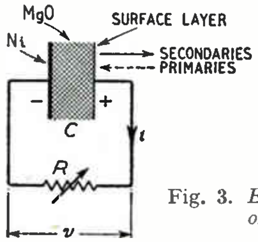

Fig. 3. *Equivalent circuit of magnesium oxide secondary emitter.*

Now, when the secondary-electron current $i_s = \delta i_p$ is liberated from the surface during the time interval dt due to primary impact, the charge $i_p\,(\delta - 1)dt$ is stored as the surface charge, giving rise to the surface voltage v. On the other hand, this voltage causes the current $i = A \exp\,(Bv)$ to flow through the resistance of the MgO layer, reaching thereby an equilibrium state at some value of v given by the following expression:

$$i_p(\delta - 1)dt - A \exp\,(Bv)dt = dq = Cdv. \quad (5)$$

Since $dv = 0$ in the steady state, we get

$$i_p(\delta - 1) = A \exp\,(Bv)$$

from which follows:

$$v = \frac{\log_e i_p(\delta - 1) - \log_e A}{B} \equiv V \quad .. \quad (6)$$

where V is the steady-state voltage; e.g., $V = 38$ V at $i_p = 100\,\mu$A for the emitter cited above (see curve 1 of Fig. 1).

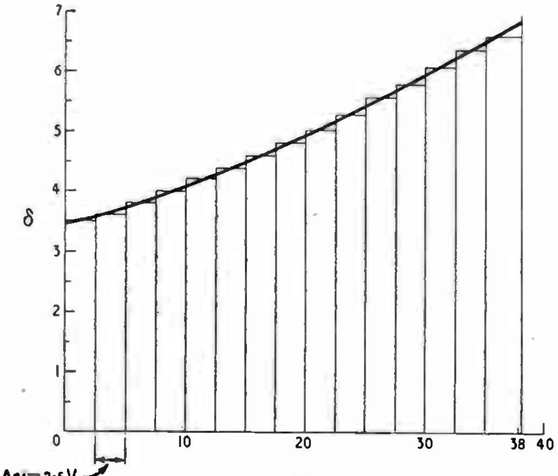

Fig. 4. *Yield versus voltage curve.*

To solve Equ. (5), let t_1 be the time taken for the voltage to change from 0 to v_1, then

$$\int_0^{v_1} \frac{dv}{i_p(\delta - 1) - A\exp(Bv)} = \int_0^{t_1} \frac{dt}{C}$$

Since δ is not constant, as shown in Fig. 2, this integration cannot, in general, be performed without recourse to an approximate calculation. To do this, the δ versus V curve in Fig. 2 must be converted into δ versus v curve, as shown in Fig. 4, which is obtained by knowing the thickness of the MgO layer, $d = 1{\cdot}58 \times 10^{-5}$ cm with the aid of Fig. 1 (curve 1) and Fig. 2. The time interval Δt for the voltage to build up from v to $v + \Delta v$ is then calculated by assuming δ to be constant during Δt. By repeating the process from $v = 0$ to $v = v_1$, and summing up, an approximate value of t_1 is given by

$$t_1 = \sum \Delta t = \sum \frac{C}{i_p(\delta - 1)B} \times \left[B\Delta v + \log_e \frac{i_p(\delta - 1) - Ae^{Bv}}{i_p(\delta - 1) - Ae^{B(v + \Delta v)}}\right] \qquad \ldots \quad (7)$$

As an example, let us assume that the cross-sectional area of the primary-electron beam is 3 sq. mm. (Kawamura's data) and the dielectric constant of MgO about 5. As the thickness of the MgO layer is about $1{\cdot}58 \times 10^{-5}$ cm, the capacitance C becomes approximately $C = 8{\cdot}4 \times 10^{-10}$ farad. Taking $i_p = 100\,\mu$A, $\Delta v = 2{\cdot}5$ V, $A = 8{\cdot}44 \times 10^{-10}$ and $B = 0{\cdot}354$ [see Equ. (3)], the values of t_1 are given as plotted in Fig. 5. The values of δ, shown in this figure, represent also the secondary-electron currents which would be obtained if the primary-electron current of $100\,\mu$A impinged upon the target with the energy of $V_p = 800$ eV.

Returning again to the equivalent circuit, shown in Fig. 3, the instant the primary-electron beam is cut off, the charge stored on the surface layer begins to decay through the resistance of the layer, the voltage across the layer decaying rapidly at first and then gradually to zero. Hence, the following equation holds good in this case:

$$\left.\begin{aligned} Ae^{Bv}\,dt &= -\,dq = -\,Cdv \\ \therefore \int_V^v \frac{dv}{Ae^{Bv}} &= -\int_0^{t_2} \frac{dt}{C} \end{aligned}\right\} \qquad \ldots \quad \ldots \quad (8)$$

Solving this equation, the following result is obtained:

$$t_2 = \frac{C}{AB}\left[e^{-Bv} - e^{-BV}\right] \qquad \ldots \quad \ldots \quad (9)$$

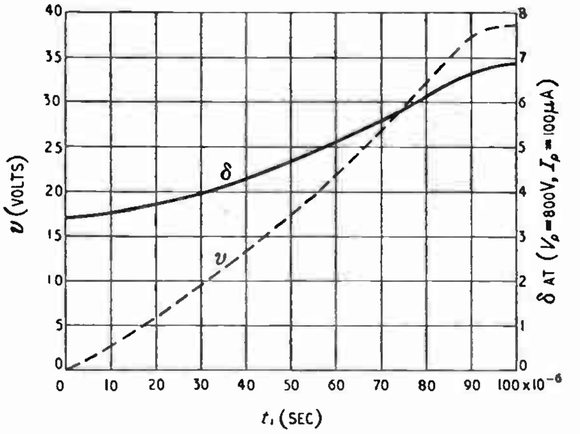

Fig. 5. *Build-up curves.* ($I_p = 100\,\mu A$, $V_p = 800\,V$).

The values given in Fig. 6 have been calculated by this equation. The values of δ in the figure have been taken from Fig. 4, but attention must be paid here to the fact that δ in this case does not represent the secondary-electron current as in the previous case, because the primary-electron current is here cut off at the instant $t_2 = 0$.

It now becomes evident that, contrary to our expectation, the time intervals required for the surface charge to build up and to decay are fairly large and that the smaller the primary-electron current density, the longer the time for build-up and the faster the decay of the voltage across the layer.

In the foregoing, the current density of the primary-electron beam has been assumed constant over the cross-sectional area, but this would not be the case in reality, the current density being maximum at the centre of the cross-section and gradually decreasing towards the margin. Therefore, the voltage across the layer will not be constant throughout the spot area, but maximum at its central part. Moreover, the capacitance C may not be correctly given by the geometrical configurations with the apparent thickness of the layer taken as the electrode spacing. Hence, the values given in Fig. 5 and Fig. 6 are to be regarded as approximations in every respect.

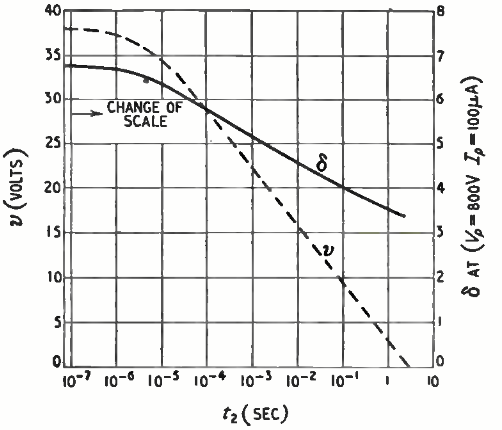

Fig. 6. *Decay curves.* (I_p = 100 µA, V_p = 800 V).

4. Amplification of a Single Rectangular Pulse or Pulses of Very Low Repetition Frequencies

Now suppose that a primary-electron beam of rectangular waveform, as shown in Fig. 7, is subjected to secondary-emission amplification, then the waveform of the secondary-electron current thereby produced will be as shown in the lower figure. The instant the primary electron current i_p impinges on the emitter surface, the secondary-electron current i_s springs suddenly up to point (a) corresponding to $\delta \approx 3{\cdot}4$, then begins to build up to point (b) corresponding to $\delta \approx 6{\cdot}85$ and remains in a steady state to point (c), where i_s decays abruptly on the cessation of the primary-electron beam i_p. If the pulse duration of the primary beam is less than about 100 microseconds, then it is unable to yield a large value of i_s owing to its incapability of attaining the steady state, as shown in the figure by the dotted line, thus failing to produce a strong electric field within the layer. δ is then far smaller than would be expected from static measurements. This is a remarkable fact which should be noted in connection with the amplification by means of secondary-emission valves of a very narrow pulse or pulses of very low repetition frequencies. The other factors which seem likely to have some effect upon the waveform of the secondary-electron current will be considered next in some detail.

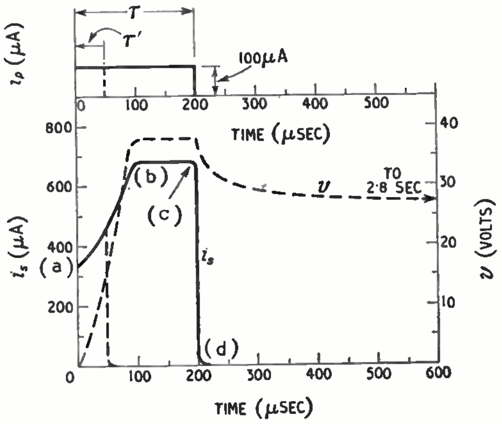

Fig. 7. *Typical waveforms of secondary-electron currents.*

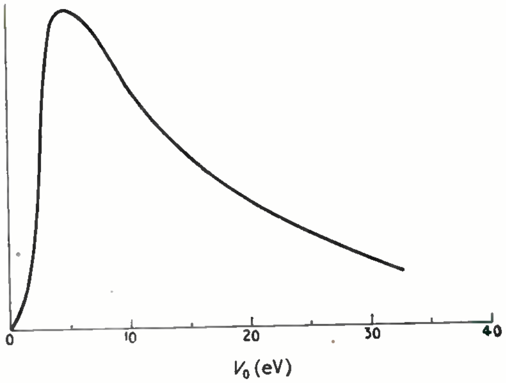

Fig. 8. *Velocity distribution of secondary electrons from MgO for 800-V primaries.*

(a) *Effect of the Exit Time upon the Waveform of the Secondary Current*

The time interval between the primary impact and the secondary emission, the exit time, has been said to be of the order of 10^{-9} sec or less for pure metals,[10] but in so far as the writer knows, no report on this subject has been published heretofore except for Hayner's data obtained in connection with shot effect of secondary-electron currents. In the writer's opinion, the following factors will be most influential in determining this time interval:

(1) The time taken by the electrons produced below the surface of the emitter to reach the surface;

(2) As mentioned above in some detail, the surface charge plays an important rôle in secondary emission from such a semi-conducting material as MgO, and it takes considerable time to build up or to decay, this presenting itself as the apparent time between the primary impact and the secondary emission;

(3) The intrinsic time involved in the mechanism of secondary emission, such as collision and transition processes.

The time mentioned above in (1) is estimated to be of the order of 10^{-13} or 10^{-14} sec by assuming the voltage across the layer to be 50 V and the mean depth about 40 atomic layers,[6] and neglecting collisions. The intrinsic time involved in collision and transition processes may also be estimated to be of the order of 10^{-14} sec.

It may, therefore, be concluded that the secondary-electron current represented by (*a*) in Fig. 7, which is supposed to be emitted from the very surface of MgO layer, may be liberated from the surface within a practically negligibly short time of the order of 10^{-13} sec after the latter has been hit by the primary electrons, thus producing practically no appreciable distortion in the waveform of the secondary-electron current.

(*b*) *Effect of the Initial Velocities of the Secondary Electrons upon the Waveform of the Secondary-Electron Current*

It is a well-known fact that the secondary electrons from pure metals have higher initial velocities than thermal electrons. Although the surface layer of the MgO emitter has a voltage of the order of a few tens of volts with respect to the base metal, it is ascertained by analyzing Kawamura's data that the energy distribution of secondary electrons may be represented approximately by the curve shown in Fig. 8, which shows a maximum at about 5 eV.

Assuming the voltage of the collecting electrode to be V_c volts with respect to the target and the initial velocity of the emitted secondary electrons V_o eV, the following equation is obtained for the transit time of the electrons from the target to collector:

$$t = \frac{1}{\sqrt{V_c}}\left[\sqrt{1+\frac{V_o}{V_c}} - \sqrt{\frac{V_o}{V_c}}\right] \times 2l \times 0{\cdot}17 \times 10^{-7}$$

$$= t_o \frac{\sqrt{1+\frac{V_o}{V_c}} - \sqrt{\frac{V_o}{V_c}}}{\sqrt{1+\frac{5}{V_c}} - \sqrt{\frac{5}{V_c}}} \quad .. \quad .. \quad .. \quad (10)$$

where l denotes the distance between the target and collector, and t_o is the transit time of the electrons having the initial velocity $V_o = 5$ eV. As an example, assume $l = 0{\cdot}2$ cm and $V_c = 100$ V; then the relation between V_o and t/t_o is as given for V_o ranging from 0 to 30 V by the curve shown in Fig. 9. In the same figure is shown the curve for η which denotes the relative number of secondary electrons having various initial velocities, the number of secondary electrons having the initial velocity of 5 eV being taken as the standard. In Fig. 10 is shown the relation between η and t/t_o. The next step is to see what effect the transit time of the secondary electrons will have upon the distortion of the waveform of the secondary-electron current.

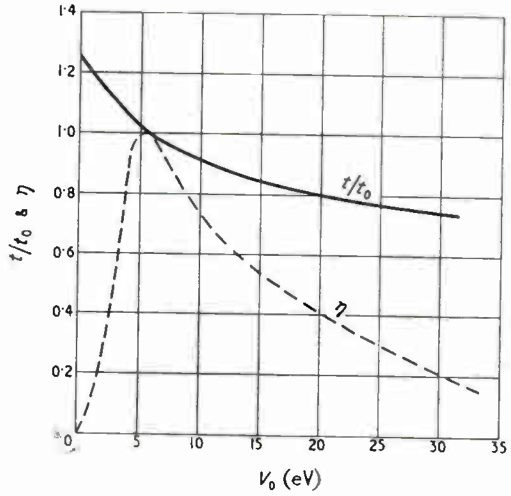

Fig. 9. *Effect of initial velocity on relative transit time and relative number.*

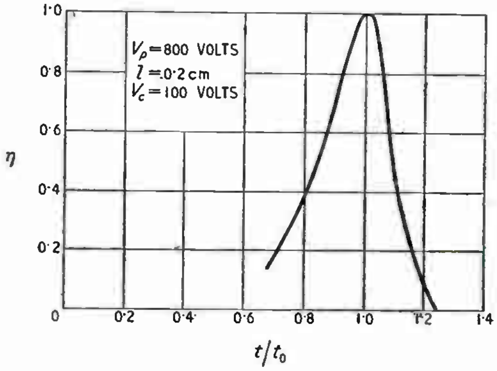

Fig. 10. *Relative number versus relative transit time.*

Now, assume that the secondary-electron current has such a rectangular waveform as shown in the upper part of Fig. 11 on emission from the target surface. Divide the pulse duration τ into a number of elements $\Delta\tau$ as shown in the figure. While those electrons having the initial velocity $V_o = 5$ eV reach the collector after the time interval t_o, those which have initial velocities faster or slower than this reach it in shorter or longer time intervals than t_o, thus giving the waveform shown hatched, which was constructed by means of the curve in Fig. 10. The number of the secondary electrons included in the hatched area is equal to $i_s\Delta\tau/e$, where e is the electronic charge. By summing up all such hatched areas the resultant waveform becomes as shown, somewhat exaggerated, by the dotted curves in the figure, which show a slight deviation from the ideal case of the full line. Calculations indicate, however, that distortion of this kind is negligibly small compared with that characteristic of MgO.

In multi-stage secondary-electron multipliers of the Zworykin type,[11] however, considerable distortion of this kind may appear, but may still be negligible compared with that characteristic of MgO described above.

Thus, it may be concluded that the waveform of the secondary-electron current resulting from the primary beam of rectangular waveform, shown in the upper part of Fig. 7, will be given by the curve shown in the lower part of the same figure.

5. Performances of the Secondary-Emission Valves at High Frequencies

As mentioned above, the secondary-electron current obtained in the collector circuit will undergo some distortion when a single primary pulse, or pulses of very low repetition frequencies, of rectangular waveform hit the target surface (see Fig. 7). When the rectangular primary current pulses hit the target surface in rapid succession and the repetition frequency becomes higher and higher, the state of affairs becomes moderately different from that of a single primary pulse. Three such examples are illustrated in Fig. 12, in which the primary pulse is $100\,\mu$A in all cases, the pulse widths and repetition periods being as denoted in the figure. It is clearly seen that, when the repetition frequencies become higher, the gain in amplification is not so reduced as in the case of a single pulse, although distortions are seen in the resultant waveform.

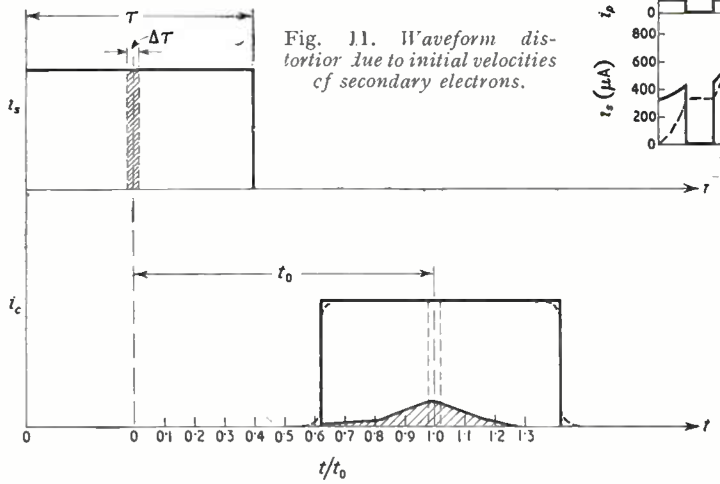

Fig. 11. *Waveform distortion due to initial velocities of secondary electrons.*

In Fig. 13 is shown another form of primary current pulses which, when subjected to the secondary-emission amplification, undergo more marked distortion in waveform. Here the pulse width is taken as 50 microseconds and the repetition period as 100 microseconds; the magnitude of the primary current is increased stepwise from $10\,\mu$A to $100\,\mu$A, and then decreased again back to $10\,\mu$A. It is to be noted here that the build-up and decay curves were calculated exactly for each value of i_p from 10 to $100\,\mu$A, by first obtaining the relation between i_p and v with the aid of Figs. 1, 2 and 4.

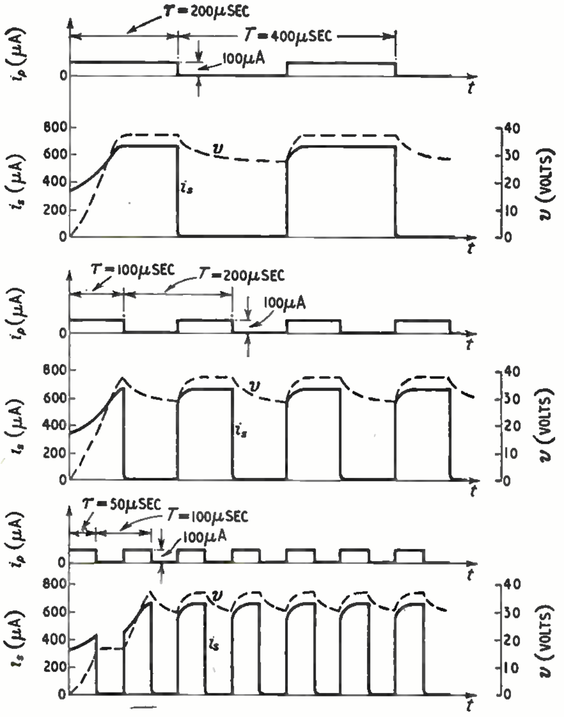

Fig. 12 (above). *Three examples of secondary-emission amplification of rectangular pulses of constant amplitude.*

If the repetition frequency becomes higher and higher, until finally the successive pulses touch each other and at the same time, the pulse width is made indefinitely narrow, the so-called class B amplification is then obtained, as shown in Fig. 14, in which the half-period is taken as 180 microseconds, and the amplitude of the primary current as $100\,\mu$A. While the first secondary-electron current pulse shows some distortion, the second and successive pulses do not show any noticeable distortion except in the regions of the skirt of the pulses, as shown in the figure, in which the chain lines represent the ideal waveform which would be obtained if MgO emitters had none of these peculiar properties. Thus, in this case, unlike that of the single pulse, the gain in secondary-emission amplification is not reduced in the least. The higher the frequency the less the distortion. Class C and class A amplification may be treated in exactly the same way, and need not be discussed any further.

Incidentally, it may be very interesting and instructive to recall the experimental data obtained by M. J. O. Strutt[12] with the secondary-emission valves of the Jonker-Overbeek type, the secondary emitter of which was made of MgO. He measured the mutual conductance of the valves at frequencies of 500 c/s and 30 Mc/s, and obtained the results of Table 1.

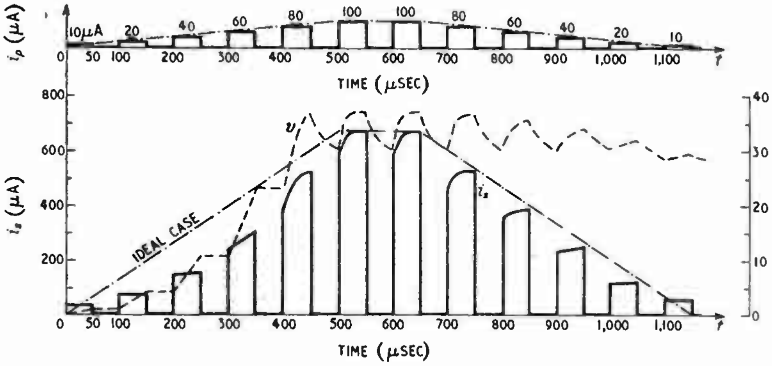

Fig. 13 (right). *Secondary-emission amplification of rectangular pulses of different amplitudes.*

Fig. 14 (below). *Secondary-emission amplification of sinusoidal wave pulses (Class B amplification).*

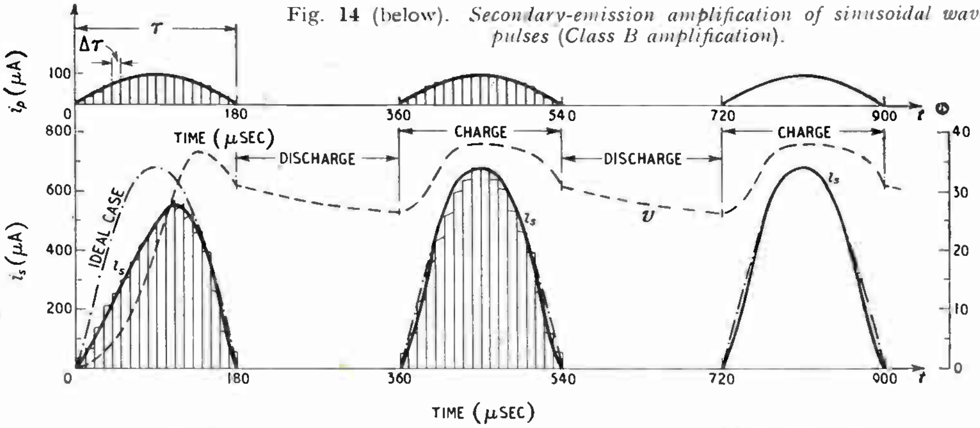

TABLE 1

Valve No.	(mA/V) at 500 c/s	(mA/V) at 30 Mc/s
1	27	3·0
2	14	5·5
3	14	7·0
4	27	2·5

This may be explained by the occurrence of the after-effect characteristic of Malter effect, for the after-effect gives rise to an increase in d.c. components and a decrease in fundamental components. It may, therefore, be said that secondary-emission valves with MgO will be effectively usable in h.f. regions if, and only if, Malter effect does not manifest itself at all.

Acknowledgment

In conclusion, the writer wishes to express his sincere thanks to Dr. Kawamura for his discussions, and also to Dr. Pomerantz, of Bartol Research Foundation of the Franklin Institute, for his cordial encouragement.

REFERENCES

[1] J. L. H. Jonker and A. J. W. M. van Overbeek. *Wireless Engineer*, 1938, Vol. 15, p. 150.

[2] H. Kawamura. Presented before the Conference on Secondary-Emission Tubes, September, 1943.

[3] R. Kollath. *Fernsehen und Tonfilm*, April/May 1941; Nijoo and Takahashi. *Applied Physics* (in Japanese), 1942, Vol. 11, p. 562; T. Arizumi and I. Oshida. *Applied Physics* (in Japanese), 1943, Vol. 12, p. 269.

[4] Italian Patent No. 372631.

[5] K. Takeya and A. Shinmen. *J. Instn elect. Engrs (Japan)*, 1943, Vol. 63, p. 946; T. Tokumitsu and K. Takeya. *J. Instn elect.Engrs (Japan)*, 1944, Vol. 5, pp. 424, 481.

[6] H. Kawamura. *Proc. Phys. Math. Soc. of Japan*, 1942, Vol. 24, p. 211.

[7] H. Seimiya, H. Fukami and M. Hirashima. Presented before the Conference on Secondary-Emission Tubes, October 1943.

[8] A. V. Joffe and A. F. Joffe. *J. Phys.*, 1940, Vol. 2, p. 283.

[9] L. Malter. *Phys. Rev.*, 1936, Vol. 50, p. 48.

[10] R. Kollath. *Z. Phys.*, 1937, Vol. 30, p. 202; L. J. Hayner. *Phys. Rev.*, 1935, Vol. 6, p. 323.

[11] L. Malter. *Proc. Inst. Radio Engrs*, November 1941, p. 587. (This paper was not obtained in Japan until February, 1950, because of the outbreak of the 1939/45 war.)

[12] M. J. O. Strutt. "Moderne Mehrgitter-Elektronenroehren," 2nd Edition, Springer, Berlin, 1940, p. 248.

CORRESPONDENCE

Letters to the Editor on technical subjects are always welcome. In publishing such communications the Editors do not necessarily endorse any technical or general statements which they may contain.

Microwave Faraday Rotation

SIR,—In connection with your July Editorial on the microwave gyrator, I should like to point out that measurements of the Faraday rotation effect in ferrites, which makes this particular realization of the gyrator practicable, were described in a short paper presented in July 1950, at the Grenoble Conference on Ferromagnetism and Antiferromagnetism.[1] The apparatus employed was essentially similar to that described by Hogan[2] except for the arrangement for suppressing multiple reflections. The rotation has been measured at these laboratories for a number of ferrites and other ferromagnetic and paramagnetic materials at room and lower temperatures, and for a range of microwave frequencies. With the exception of liquid oxygen[3] fairly close agreement has been obtained in the more recent measurements between the measured and predicted rotations.

Although, perhaps, of only academic interest in the present connection, it should also be noted that the optical and microwave Faraday effects in ferromagnetics originate in fundamentally different (yet superficially similar) mechanisms.

F. F. ROBERTS.

Post Office Research Station,
Dollis Hill, London, N.W.2.
29th July 1952.

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[1] Roberts, 1951, "A Note on the Ferromagnetic Faraday Effect at Centimetre Wavelengths," *J. Phys. Radium*, Vol. 12, pp. 305-7.

[2] Hogan, 1952, *Bell Syst. Tech. J.*, Vol. 31, pp. 1-31.

[3] Roberts, 1952, "Microwave Faraday Rotation in Liquid Oxygen," *Proc. Phys. Soc.*, Vol. 65B, p. 460.

The Dromgoole Effect

SIR,—I read with considerable interest Professor Howe's Editorial, "Effect of Torsion on a Longitudinally-Magnetized Iron Wire," in your May 1952 issue, because this Laboratory has been experimenting with a similar phenomenon. If a rod of magnetic material is subjected simultaneously to an axial and a circular magnetic field, a slight axial twist is produced. This phenomenon is known as the Wiedemann effect.[1] If the rod is magnetized longitudinally and then is twisted, circular magnetization is produced, as described in the Editorial. Likewise if the rod is magnetized circularly (by passing current through it in an axial direction) and then is twisted, axial magnetization is produced and can be measured by a coil wound on the rod. Both of these inverse Wiedemann effects were investigated by Honda and Nagaoka. Theoretical and experimental results and numerous references to other work are given in Honda's book.[2]

The second of these two inverse Wiedemann effects was called to the attention of this Laboratory by Mr. Robert Briggs, formerly of the Ames Aeronautical Laboratory, Moffett Field, California, something over a year ago, and has been under study here by Mr. Thomas A. Garber and also by Mr. James L. Arbogast, who recently completed a thesis[3] on the subject under my supervision.

Honda reports only the results of fixed levels of magnetization followed by steps of twist. Arbogast tried pure iron and Hipernik, and was able to reproduce Honda's results on iron qualitatively, and found also that if the order of procedure is reversed, that is, if a fixed twist is held and then the magnetization is applied, the end results for the same combination of twist and magnetizing current are not the same for the two orders of procedure. For use as a gauge, however, Arbogast used alternating-current excitation (as did Mr. Dromgoole) and used as his indication of twist the filtered inphase component of the voltage induced in the pick-up coil. This voltage is phase sensitive to the direction of twist and has a fairly clear null and good linearity. In these respects the Hipernik is considerably superior to pure iron. The pure iron was tried in hope of obtaining an understanding of the phenomenon more readily than seemed likely from study of an alloy. The development has by no means as yet achieved a design for a practical gauge.

Development work for utilization of the effect is proceeding also at the Ames Aeronautical Laboratory, but report of the status of that work is not the function of this writer.

R. H. FRAZIER.

Massachusetts Institute of Technology,
Cambridge, Mass., U.S.A.
15th July 1952.

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[1] G. Wiedemann. "Magnetische Untersuchungen." *Annalen der Physik und Chemie*, Vol. 17, Ser. 4, pp. 193-217, 1862.

[2] K. Honda. "Magnetic Properties of Matter." Ch. III (original Japanese edition, Syokwabo and Company, Tokyo, 1917; English translation, 1928).

[3] James L. Arbogast. "An Investigation into the Inverse Wiedemann Effect." S.B. Thesis, Massachusetts Institute of Technology, Cambridge, Mass., May 1952.

NEW BOOKS

Antennas: Theory and Practice

By S. A. SCHELKUNOFF and H. T. FRIIS. Pp. 639 + xxii, with 378 illustrations. Chapman & Hall, Ltd., 37 Essex Street, London, W.C.2. Price 80s.

The authors are both well-known members of the staff of the Bell Telephone Laboratories and Dr. Friis is the Director of Radio Research. This book is one of an applied mathematics series and it is interesting to note that in the same series Dr. Schelkunoff has just published a book entitled "Advanced Antenna Theory", dealing "in rigorous fashion with the theory behind antenna behaviour." It is about a third of the size of the book under review, which, the authors say, expresses their idea of what a college textbook on antennas should contain.

The material is divided into 19 chapters and the authors enumerate five chapters which they consider would form a short undergraduate course, and then four more if it is desired to extend the course, but much of the book is of a post-graduate standard.

The titles of the chapters are as follows:—physical principles of radiation, Maxwell's equations; plane waves; spherical waves; directive radiation; directivity and effective area; waves over ground; antenna current; impedance, reciprocity, equivalence; small antennas; self-resonant antennas; general theory of linear antennas; impedance of dipole antennas; rhombic antennas; linear antenna systems; horns; slot antennas; reflectors; lenses.

The book deals very thoroughly with antenna principles and the theory of radiation; it stresses physical ideas and pictures as well as quantitative analysis. The vector concept is employed but the authors state in the preface that they do not use vector analysis because in the type of problem with which they are concerned "it impedes rather than promotes understanding." They avoid methods devised by mathematicians for mathematicians, which are "only satisfactory for those readers who are on such familiar terms with mathematics that they hardly notice it." The fundamental theory is, however, very fully developed and applied to all types of antennas, as the above chapter headings indicate, and this cannot be done without a considerable amount of mathematics. It must be remembered that the book is one of an applied mathematics series. As the authors state in the preface, they try to close the gap between circuit and field theories, which exists when they are developed independently.

It is interesting to note that they give great credit to Dr. H. C. Pocklington, F.R.S., who in 1897 published a paper entitled "Electrical Oscillations in Wires" in the *Cambridge Phil. Soc. Proc.* They say that much practical antenna theory has been based on this work of an apparently forgotten man. "Some radio engineers call it a practical engineering approximation, and some theoreticians once called it a colossal fraud." The authors devote a whole chapter to the sinusoidal approximation demonstrated by Pocklington, and the various factors associated with it.

Most chapters conclude with a large number of problems. Many references are given both as footnotes and at the end of most chapters. There are 10 appendices mostly containing tables of formulae and constants for various types of antenna. The book is excellently produced and has obviously been prepared with great care and meticulous accuracy. It is undoubtedly a most valuable addition to the literature of the subject.

G. W. O. H.

Thermionic Valve Circuits—3rd Edition

By Emrys Williams, Ph.D., B.Eng., M.I.E.E., M.Brit.I.R.E. Pp. 314 + xi, with 213 illustrations. Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price 21s.

This edition has been so much expanded that it is desirable to consider it as a new book rather than as merely a new edition. It is not a collection of circuits, as its title might lead some to suppose, but is a textbook covering the theory of circuits used with valves. It has eight chapters and it starts with one which summarizes the a.c. theory and mathematics required for an understanding of the rest. There is then a chapter on the valve itself which, in 17 pages, covers the bare essentials of valve fundamentals.

After this there are two chapters on amplifiers, one on regeneration and oscillation and another on detectors and rectifiers. Chapter 7 covers frequency-changers and modulators and the last chapter deals with pulses and pulsed circuits. "A knowledge of alternating current theory and of mathematics up to the standard of a university student at the end of his second year" is assumed.

The book covers the more important forms of the older circuits and many of the newer types, such as multivibrators, Miller integrators and so on. The treatment is adequate from the theoretical side and is by no means highly mathematical. It is one which will unquestionably appeal to those who want something more solid than the pure explanation but do not require the complex mathematics of many analytic books.

There are a few errors and misleading statements. On p.66, it is stated that, with cathode bias, grid-circuit coupling is better than a by-pass capacitor across the bias resistor, and an explanation is given of how to include it. All this is quite correct as long as it is possible to use the circuit described but this circuit demands that both terminals of the input voltage source should be separate from negative h.t. Practically speaking, grid-circuit decoupling is possible only with transformer coupling and rarely with RC coupling which is the commonest one of all. The author fails to mention this and it is rather much to expect the beginner to realize the limitation of the circuit.

Then on p.148, equation (V.15), for the ratio of the two capacitances of a Colpitts' oscillator, is given. The equation gives only one limit to the ratio whereas, in fact, there are two. It is well known, and easily shown on physical grounds, that the circuit will not oscillate if the ratio is either too large or too small. The author makes no mention of this which is rather surprising in view of the treatment of the Hartley oscillator, which is correctly carried out to give two limiting positions for the cathode tap.

These are small points in a book containing so much useful information and having so clear a presentation. There is no doubt that the author has succeeded in his aim of producing a book which shall be useful for use in universities and technical colleges.

W. T. C.

Messtechnik für Funkingenieure

By Friedrich Benz. Pp. 513 + xvi, with 399 illustrations. Springer-Verlag, Vienna.

In the October 1950 issue we reviewed the fourth edition of the author's *Einführung in die Funktechnik*, a book of 736 pages. The book under review is confined to measurements. The author was not only a Professor but for 10 years was also Director of the Government Radio Research Laboratories in Vienna. The book is divided into five sections. The first is a short general review of the subject of measurements, units, sensitivity, accuracy, etc. The second section deals with current sources of various types, both sinusoidal and saw-tooth, and methods of controlling them; resistances, capacitors, and inductors; amplifiers, potential dividers, valve voltmeters, direct-reading and recording instruments. The third section discusses methods of measurement of voltage, current, power, phase-angle, resistance, self and mutual inductance, capacitance, magnetic properties, frequency, waveform, acoustic phenomena, and finally, electric field strength. The fourth section deals with the application of all these methods of measurement to the testing and investigation of the various items of radio equipment from a primary cell to the transmitting aerial. The final section is devoted to the production of microwaves and their application to measurement and testing.

The Mie system of units is employed; i.e., the cm. k.s. system. The book is very well arranged so that one can easily turn to any desired measurement. The field covered is so wide that it was impossible in the available space to give the theory and the derivation of all the formulae, but references are liberally provided in footnotes on nearly every page, in addition to which there is an index with 3,000 items. The book will undoubtedly serve as a very useful reference book in any radio laboratory; it will either give you the desired information or tell you where you can find it if you wish to probe more deeply into the subject.

G. W. O. H.

CORRECTIONS

Two typographical errors occurred in the paper "Spectrum of a Frequency-Modulated Wave," by W. C. Vaughan, which appeared in the August issue. On page 219, a term γ was omitted in Bessel's equation and should be inserted between the bracket and the equality sign. On page 219, right-hand column, 30th line and on page 220, left-hand column, second line, $m + 1/m$ should read $(m + 1)/m$.

In last month's Editorial, "Ionic Bombardment of Silicon," the word 'selenium' appeared in three places instead of 'silicon.' All the references should, of course, have been to silicon.

ABSTRACTS and REFERENCES

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research and published by arrangement with that Department.

The abstracts are classified in accordance with the Universal Decimal Classification. They are arranged within broad subject sections in the order of the U.D.C. numbers, except that notices of book reviews are placed at the ends of the sections. U.D.C. numbers marked with a dagger (†) must be regarded as provisional. The abbreviations of the titles of journals are taken from the World List of Scientific Periodicals. Titles that do not appear in this List are abbreviated in a style conforming to it.

ACOUSTICS AND AUDIO FREQUENCIES

016 : 534 **2406**

References to Contemporary Papers on Acoustics.—R. T. Beyer. (*J. acoust. Soc. Amer.*, March 1952, Vol. 24, No. 2, pp. 234–243.) Continuation of 1797 of July.

534.2 **2407**

Transient Phenomena in Sound Transmission.—A. Darré. (*Frequenz*, March 1952, Vol. 6, No. 3, pp. 65–71.) Discussion of phenomena concerned in the production of linear distortion only, with particular reference to frequency response, phase relations and group transit time. The characteristics of moving-coil and horn-type loudspeakers are considered and also the effect of room reverberation on the response curve of a loudspeaker.

534.213.4-13 **2408**

The Propagation of Sound through Gases contained in Narrow Tubes.—L. E. Lawley. (*Proc. phys. Soc.*, 1st March 1952, Vol. 65, No. 387B, pp. 181–188.) Results for air, O, H and N at frequencies between 60 and 150 kc/s indicate a viscosity/thermal-conductivity constant 5% above the theoretical value.

534.23 : 534.321.9 **2409**

Transmission of Ultrasonic Waves through a Thin Solid Plate at the Critical Angle for the Dilatational Wave.—K. R. Makinson. (*J. acoust. Soc. Amer.*, March 1952, Vol. 24, No. 2, pp. 202–206.) The transmission through an isotropic plate immersed in a liquid is examined experimentally and theoretically. Total reflection occurs near the critical angle for a considerable range of thickness of plate. It is therefore possible to measure the velocity of the dilatational wave in a solid even when only thin specimens are available.

534.23-16 **2410**

Spherical-Wave Propagation in Solid Media.—F. G. Blake, Jr. (*J. acoust. Soc. Amer.*, March 1952, Vol. 24, No. 2, pp. 211–215.) Analysis shows that when an impulsive pressure is generated in a spherical cavity in an infinite solid medium, a damped oscillatory wave train is radiated which differs essentially from the form of the original pressure pulse.

534.23-16 **2411**

Transmission of Sound through Plates.—A. Schoch. (*Acustica*, 1952, Vol. 2, No. 1, pp. 1–17. In German.) Theory for plane waves and limited beams is developed in a form clearly showing the connection with free waves in plates. Cremer's concept of total transmission as 'coincidence' of the incident wave with a free wave in the plate is critically discussed. Experiments with Al plates and ultrasonic waves give results in good agreement with theory.

534.231 **2412**

A New Expansion for the Velocity Potential of a Piston Source.—A. H. Carter & A. O. Williams, Jr. (*J. acoust. Soc. Amer.*, March 1952, Vol. 24, No. 2, p. 230.) Correction to paper abstracted in 1815 of 1951.

534.232 **2413**

Radiation Loading of a Piston Source in a Finite Circular Baffle.—R. B. Watson. (*J. acoust. Soc. Amer.*, March 1952, Vol. 24, No. 2, pp. 225–228.) Experimental results are given for baffle dimensions of the order of a wavelength. Examination of the results shows the lack of suitable expressions for calculations.

534.24 : 534.321.9 **2414**

Lateral Displacement of a Totally Reflected Ray at Ultrasonic Frequencies.—A. Schoch. (*Acustica*, 1952, Vol. 2, No. 1, pp. 18–19. In German.) Schlieren photographs of 5·5-Mc/s and 16-Mc/s waves reflected from an Al plate in xylol clearly show this displacement, which occurs at the angle of incidence for which a Rayleigh wave is excited in the solid.

534.26 **2415**

The Diffraction of a Plane Sound Pulse Incident Normally on a Regular Grating of Perfectly Reflecting Strips.—E. N. Fox. (*Proc. roy. Soc. A.*, 6th March 1952, Vol. 211, No. 1106, pp. 398–417.) The general methods previously described (2417 of 1949) are used to find the pressure on both sides of gratings whose aperture areas are $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$ of the total grating area. Both the exact solution and an asymptotic solution for use in the later stages, when exact calculation becomes too laborious, are discussed. The results of both solutions are shown graphically. The analysis can be extended simply to rectangular pulses of finite duration.

534.321.9 : 534.232].047 **2416**

The Biological Effect of High-Level Complex Noise (Ultrasonic Region of the Spectrum).—P. Bugard. (*Ann. Télécommun.*, March 1952, Vol. 7, No. 3, pp. 139–143.) Pen and c.r.o. recordings of the output of a Hartmann whistle for different adjustments of the compressed-air jet are discussed and the corresponding auditory sensations are noted. Two distinct types of output, depending on the jet adjustment, are identified: (*a*) a fairly pure high-level ultrasonic wave; (*b*) white noise of higher mean level.

534.41 **2417**

A Detector of Transients and its Applications to the Study of Music and Speech Signals.—A. Moles & G. Corsain. (*Radio franç.*, March 1952, No. 3, pp. 1–7.) Discussion of equipment designed to isolate the transients from the envelope of the energy spectrum and to effect their summation. Preliminary results obtained on signals derived from speech in different languages, orchestral, piano and violoncello music, and logatoms formed by coupling selected consonants and vowels, are shown and discussed.

534.7 **2418**

Recovery of the Auditory Threshold after Strong Acoustic Stimulation.—I. J. Hirsh & W. D. Ward. (*J. acoust. Soc. Amer.*, March 1952, Vol. 24, No. 2, pp. 131–141.) The elevation of the threshold after fatigue by pure tones and white noise was measured. Recovery to about the normal value usually occurs during the first minute, followed by an increase reaching a maximum about two minutes after the cessation of the fatiguing tone. In some cases a minor maximum occurs about five minutes later.

534.75 **2419**

Auditory-Psychological [hörpsychologische] **Acoustics.**—P. Burkowitz. (*Funk u. Ton*, March 1952, Vol. 6, No. 3, pp. 136–140.) Summary of the essentials of a new theory of the basic principles of single-channel transmission and reception of sound.

534.845 **2420**

Comparative Reverberation-Room Measurements of the Absorption Coëfficient of Sound-Absorbent Materials.—G. Venzke. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, Jan./Feb. 1952, Vol. 4, Nos. 1/2, pp. 1–3.) The results of measurements in eight laboratories of the absorption coefficient of hallonit, a rock-wool material made in slabs 40 × 40 × 3 cm, are shown graphically. The size of the test surface used had no appreciable effect on the results, and measurement accuracy was about the same for warble-tone and white-noise sources. No dependence of the results on the shape and size of the test chamber could be found. Two sets of measurements by a Kundt's-tube method (perpendicular incidence) gave values of the maximum absorption coefficient about 15–20% less than the mean value given by the reverberation measurements, in which surface areas of $7\cdot5\ \text{m}^2$ or $15\ \text{m}^2$ were used, in general distributed on two adjacent walls and the floor of the test chamber.

534.846 **2421**

Acoustics of the Remodeled House and Senate Chambers of the National Capitol.—P. E. Sabine. (*J. acoust. Soc. Amer.* March 1952, Vol. 24, No. 2, pp. 121–124.) Details are given of the materials and dispositions of sound-absorbing surfaces used, together with the results of articulation tests showing the excellent performance obtained.

534.85 **2422**

Thorn Needles.—S. Kelly: A. M. Pollock. (*Wireless World*, June 1952, Vol. 58, No. 6, pp. 243–244.) Further discussion on 2089 of 1951 (Pollock) and author's reply.

534.851 **2423**

Phonograph Needle-Drag Distortion.—J. Rabinow & E. Codier. (*J. acoust. Soc. Amer.*, March 1952, Vol. 24, No. 2, pp. 216–225.) Analysis indicates that tangential motion of the tip of a pickup needle will occur and may cause distortion of the output signal. Attempts to detect such distortion were unsuccessful owing to the presence of other distortions which masked it.

534.861.2 **2424**

Helmholtz Resonators in the Acoustic Treatment of Broadcasting Studios.—C. L. S. Gilford. (*Brit. J. appl. Phys.*, March 1952, Vol. 3, No. 3, pp. 86–92.) "A theory of the action of Helmholtz resonators as sound absorbers is presented, covering both the isolated resonator and regular arrays. Experiments in reverberation rooms and acoustically treated studios are described and general recommendations for design are given. Regular arrays are preferable to single resonators, openings being made more resistive by covering with a fabric. It is concluded that great variations in design to suit architectural requirements may be made without loss of effectiveness, and the widths of the frequency band over which absorption takes place may be varied between wide limits."

621.395.623.8 **2425**

Centralized Public-Address System.—(*Telefunken Ztg*, March 1952, Vol. 25, No. 94, pp. 68–70.) Recent investigations indicate that for large audiences better results are obtained by using one or two vertical arrays of loudspeakers at a central point than by means of many loudspeakers distributed over the area to be covered. For vertical arrays the sound pressure increases with distance up to a certain point. With two vertical arrays (each with 48 loudspeakers) of overall length 7 m and raised 6 m above the ground, a 300-W amplifier sufficed to give good sound distribution to a crowd of 300 000 people assembled in the holy place Fatima, Portugal.

621.395.625.2 **2426**

New Sound Reproducer for Engraved-Tape Records.—P. Hémardinquer. (*TSF et TV*, March 1952, Vol. 28, No. 281, pp. 113–114.) Description of commercially available equipment using a piezoelectric head with sapphire needle for reproduction from records on wax-coated tape.

621.395.625.3 **2427**

An Investigation into the Mechanism of Magnetic-Tape Recording.—P. E. Axon. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 109–124. Discussion, pp. 124–126.) Asymmetry of hysteresis loops is found to give distinctive properties to recording and distortion characteristics of unbiased recording. The properties have been confirmed experimentally. The mechanism of recording using high-frequency bias is examined. Predictions are made concerning transitions to be expected in the characteristics as the high-frequency bias field is increased from zero to saturation value; these are experimentally confirmed. Adequate high-frequency bias eliminates the asymmetry of the a.f. intensity variation. The effect of a bias-leakage field outside the recording gap is discussed with reference to the coercivity of the tape material.

621.395.625.3 **2428**

A New Recording Medium for Transcribed Message Services.—J. Z. Menard. (*Bell Syst. tech. J.*, May 1952, Vol. 31, No. 3, pp. 530–540.) A magnetic recording medium composed of rubber impregnated with magnetic oxide and lubricant, and used in the form of moulded bands, is found particularly suitable for applications involving repetition of short messages.

AERIALS AND TRANSMISSION LINES

621.315.212 **2429**

Elements with Rotational Symmetry for Coaxial-Cable Junctions.—H. Meinke & A. Scheuber. (*Fernmeldetech. Z.*, March 1952, Vol. 5, No. 3, pp. 109–114.) General explanation of the properties of units with sudden changes of conductor diameters or uniform variation of diameter and change of dielectric. The design of such units for reflection-free connection of cables with different characteristic impedances is outlined. A simple conversion rule is given which enables the calculations to be applied to lines of different characteristic impedance.

621.392 : 621.396.67 **2430**

Anti-Resonant H.F. Transmission Lines, Input Impedance Characteristics.—H. M. Barlow. (*Wireless Engr*, June 1952, Vol. 29, No. 345, pp. 145–147.) Treatment of the short-circuited $\lambda/4$ line, deriving convenient expressions for the maximum value of the resistive component R_s and of the reactive component X_s of the input impedance. $R_{s,max} \approx 2X_{s,max}$. The lengths of line at which these maxima occur are slightly different.

621.392.2 : 621.396.67 **2431**

A Cage Type of Feeder.—A. Schweisthal. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, March/April 1952, Vol. 4, Nos. 3/4, pp. 45–47.) Description of feeder lines for broadcasting aerials. At Coblenz, Saarbrücken, Bad Dürrheim and Ravensburg the lines are 200 m long; that for the Rhine transmitter has a length of 500 m. The central conductor is a Cu tube (2 cm diam.) with joints hard soldered and is supported by an internal steel-wire rope under 500 kg tension. The outer screen consists of twelve 3-mm Cu wires evenly spaced round a circle of diameter 50 cm and with a similar total tension. Insulated supports, carried on poles 6 m high, are provided at 12-m intervals for both core and wires, the latter having short-circuiting rings at the ends. The characteristic impedance is about 205 Ω. Attenuation is considerably less than for a 9·5/36 cable and total cost much less.

621.392.21 **2432**

Note on the Variations of Phase Velocity in Continuously-Wound Delay Lines at High Frequencies.—I. A. D. Lewis. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, p. 158.) Discussion on 2637 of 1951.

621.392.26 **2433**

The Completeness of the System of E- and H-Type Waves in Waveguides.—E. Ledinegg & P. Urban. (*Arch. elekt. Übertragung*, March 1952, Vol. 6, No. 3, pp. 109–113.) It is proved mathematically that the solutions corresponding to the E-type and H-type waves represent all the possible solutions of Maxwell's equations, and that the plane waves in waveguides constitute a complete system in this sense. An essential element in the proof is the assumption of a finite value for the e.m. field at infinity.

621.392.26 **2434**

The Impedance of Unsymmetrical Strips in Rectangular Waveguides.—L. Lewin. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 167–168.) Summary only. Formulae are derived for the impedance of inductive and capacitive strips situated either centrally or unsymmetrically in a waveguide.

621.392.43 **2435**

The Use of Directional Couplers in Aerial-Matching Problems.—S. Gratama. (*Tijdschr. ned. Radiogenoot.*, March 1952, Vol. 17, No. 2, pp. 85–102.) The operation of the coaxial-line reflectometer is described; this incorporates two directional couplers, measuring the intensity of the original and reflected waves respectively. Advantages of this instrument over the standing-wave indicator include wide frequency range, absence of moving parts, rapid operation. Calculations are made for an experimental model for the frequency band 5–500 Mc/s. A method is described for obtaining a c.r.o. indication of the bandwidth of an aerial.

621.396.67 **2436**

A Note on Booker's Extension of Babinet's Principle.—R. S. Elliott. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, p. 729.) Discussion showing that Booker's extension of Babinet's principle (1335 of 1947) is only applicable to a restricted class of apertures with symmetry about the polarization axis of the primary source.

621.396.67 **2437**

A New Solution for the Current and Voltage Distribution on Cylindrical, Ellipsoidal, Conical or Other Rotationally Symmetrical Aerials.—O. Zinke. (*Frequenz*, March 1952, Vol. 6, No. 3, pp. 57–65.) The method is based on the solution of the static potential equation $\Delta\phi = 0$. For rotationally symmetrical aerials the solution can be effected either by means of electrolyte-tank measurements, or graphically, or by Southwell's relaxation methods. The e.s. field strength normal to the metal surface is thus known and the charge per unit length of the surface contour is deduced. Only in exceptional cases, such as homogeneous cables or ellipsoidal aerials, is the charge per unit length independent of position. In the dynamic case the current and voltage distributions are sinusoidal only in these special cases. Constant charge per unit length in the static case thus corresponds to sinusoidal current distribution in the dynamic case, and nonuniform static charge density to nonsinusoidal current distribution. The scalar potential along cylindrical transmission lines and aerials is sinusoidal; on circular plates it is given by Bessel's functions. The theory is applied to the determination of the charge, current and voltage distributions along a cylindrical aerial for the cases of current resonance ($l \sim \lambda/4$) and voltage resonance ($l < \lambda/2$).

621.396.67 **2438**

Theory of Multiple-Feed Aerials.—R. Walter. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, Jan./Feb. 1952, Vol. 4, Nos. 1/2, pp. 12–16.) Analysis shows that a current distribution corresponding to the function e^{-x^2} gives a good directional characteristic for a broadcasting aerial, but that even better characteristics can be obtained with multiple-feed arrangements. Vertical directional characteristics are shown for a system of two aerials, of heights λ and $\lambda/2$, independently fed at the foot, the ratio of the currents having the values 1·5, 2, 2·5, 3 and 4. Corresponding characteristics for single homogeneous aerials of heights $0{\cdot}56\lambda$ and $0{\cdot}625\lambda$ are included for comparison. The current ratio 4 gives the closest approximation to the Gaussian curve, but in practice a ratio of 2·5 or 3 is preferred. The $0{\cdot}625\lambda$ single aerial has a null point at 37°, but a side lobe with an amplitude 31% of that of the horizontal radiation. Any further increase of height is consequently not permissible. With the double-aerial system, improvement of the directional characteristic by increase of aerial height is practicable up to $1{\cdot}2\lambda$, while for a triple-aerial system with triple feed, improvement of the characteristic is theoretically possible up to a height of about $1{\cdot}8\lambda$.

621.396.67 **2439**

Experience with Double-Feed Medium-Wave Aerials.—A. Schweisthal. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, March/April 1952, Vol. 4, Nos. 3/4, pp. 52–59.) The aerials at Bad Dürrheim and Ravensburg are essentially similar and consist of square-section lattice masts 120 m high, insulated at the foot and with an insulating section at a height of 75 m. The lower section forms a 175-Ω transmission line, with a galvanized-iron tube as core, for feeding the upper section. Copper tubes connect the tubular core and the foot of the lower section with the aerial tuning network used for adjusting the location of the potential node. The observed vertical radiation diagram is shown together with the calculated one. For the Rhine transmitter, the required 2 : 1 or 3 : 1 concentration of the radiation in the NW-SE direction is effected by means of two 150-m aerials, divided at a height of 80 m and located 100 m (about $\lambda/3$) apart on a NW-SE line. These are fed in antiphase with a prescribed power ratio. A diagram shows the horizontal radiation pattern (*a*) with one mast fed at the foot and the other earthed, (*b*) with double feed for both masts. A method of measuring the potential distribution on a transmitting aerial is outlined in an appendix.

621.396.67 : 621.397.62 **2440**

Television Receiving Aerials.—F. R. W. Strafford. (*Wireless World*, June & July 1952, Vol. 58, Nos. 6 & 7, pp. 213–218 & 264–267.) The characteristics of simple dipole and multi-element types of aerial are discussed; calculated and measured values of impedance are plotted against frequency for two types of dipole for channel 4. In receiving aerials, losses due to mismatching are less important than those due to feeder attenuation. With present British television standards there is no advantage in using folded dipoles, though the greater bandwidth corresponding to the French 819-line standard does require their use. Problems involved in making measurements on aerials are examined, and some aspects of indoor aerials and the mechanical design of outdoor aerials are discussed.

621.396.671 : 537.311.5 : 538.569 **2441**

On the Current Induced in a Conducting Ribbon by the Incidence of a Plane Electromagnetic Wave.—E. B. Moullin & F. M. Phillips. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 165–166.) Summary only. The analysis in terms of Mathieu functions given by Morse & Rubenstein (905 of 1939) for the diffraction of plane waves by ribbons and slits is extended, and the distribution of current density in ribbons of widths λ/π, $2\lambda/\pi$ and $4\lambda/\pi$ is evaluated. The results show that, in the range of widths examined, the distribution of both the in-phase and the quadrature component near the edge depends very little on the width of the ribbon. The distribution is practically the same as that near the edge of a half-plane, for which a solution has previously been given. The disturbed density is largely concentrated in a region very near the edge and can be replaced by an equivalent filament for the purpose of predicting the polar diagram. A practical treatment is thus available which does not involve laborious mathematics. A curve is given showing the strength of the echoed field as a function of ribbon width; this is valid down to zero width.

621.396.677 **2442**

An Annular Corrugated-Surface Antenna.—E. M. T. Jones. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 721–725.) Analysis is presented for an aerial system which is the axially symmetrical counterpart of the rectangular aerial discussed by Reynolds & Lucke (922 of April). The surface wave is easily excited from the end of a coaxial line, with the centre conductor extending $\lambda/4$ above the surface of the aerial. The far-zone radiation pattern is uniform in the azimuthal direction and polarized in a direction perpendicular to the surface. The major lobe is directed slightly above the plane of the aerial. Experimental results for an aerial operating at a wavelength of about 4 cm, in a finite ground plane, are in good agreement with theory.

621.396.677 **2443**

A New Type of U.H.F. Lens [aerial].—J. C. Simon. (*Onde élect.*, April/May 1952, Vol. 32, Nos. 301/302, pp. 181–189.) Theory shows that the usual defects of u.h.f. aerial systems are not due to diffraction effects difficult to calculate, but to phase aberrations analogous to those met with in optical instruments. For this reason, in the aerial systems for the Paris-Lille link phase-correction methods are adopted. The aerials consist of two elements, one being a small waveguide horn radiating towards a concave hyperbolic reflector of diameter 150 cm, which is rigidly attached, by means of a conical metal structure, to the second element, a special lens of variable index of refraction, constructed from metal plates drilled with circular holes of wavelength dimensions and with an aperture of 7m^2. Phase correction is applied to both elements of the system, and it is possible to correct local phase defects. The resulting beam has a half-power width of 1·7°, and the first ring at 4° from the axis is 20 db below the main lobe. The measured gain is about 38·5 db for the 7-m^2 area and the s.w.r. is $<1{\cdot}12$ in a band of 300 Mc/s centred on 3·64 kMc/s. See also 970 of April and 820 of 1951 (Ortusi & Simon).

621.396.677 : 537.226 **2444**

Isotropic Artificial Dielectric.—Corkum. (See 2523.)

621.396.677 : 621.396.9 **2445**

A Family of Designs for Rapid-Scanning Radar Antennas.—R. F. Rinehart. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 686–688.) Analysis resulting in the design of lenses with smaller feed circles than those of the lenses previously described (1593 of 1949), thus permitting rapid rotation of the source.

621.396.677.012.71 + 621.396.81 **2446**

Aerial Measurements in the Microwave Range.—J. M. G. Seppen. (*Tijdschr. ned. Radiogenoot.*, March 1952, Vol. 17, No. 2, pp. 63–83. Discussion, p. 84.) Energy radiation and collection in the wavelength range 3–10 cm are discussed generally. Various methods of obtaining radiation characteristics are mentioned, and an account is given of the method used for measurements over the path from Den Helder to Tessel, readings being taken at successive 10′ aerial rotation angles. The equipment is described, with special attention to the attenuator. Tidal effects over the sea path, and atmospheric scattering and attenuation are taken into account.

621.396.677.029.64 **2447**

A Practical Method for the Design of Parabolic Aerials for Microwaves.—J. Deschanps & G. G. Esculier. (*Onde élect.*, April/May 1952, Vol. 32, Nos. 301/302, pp. 209–213.) Description of a simple method for determining the contour of a reflector excited by a waveguide horn, and for evaluating the horn dimensions, for specified radiation characteristics. No elaborate mathematics is required.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.013.5 : 621.3.011.23 : 621.314.2.045 **2448**

Calculation of the Magnetic Field created by Conductors of Rectangular Cross-Section in a Slot, and its Application to the Determination of the Reactance of

Transformer Windings.—E. Billig. (*Rev. gén. Élect.*, March 1952, Vol. 61, No. 3, pp. 135–149. Correction, *ibid.*, April 1952, Vol. 61, No. 4, p. 196.) French version of paper abstracted in 602 of March.

621.3.015.7 : 621.387.4 **2449**

A Single-Channel Pulse-Amplitude Analyser for Measurement of Coincident Pulses.—R. Wilson. (*J. sci. Instrum.*, March 1952, Vol. 29, No. 3, pp. 70–72.)

621.314.3† : [621.396.615.17 + 621.396.619.2 **2450**

The Use of Saturable Reactors as Discharge Devices for Pulse Generators.—W. S. Melville. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 156–157.) Discussion on 2362 of 1951.

621.316.8.029.53/.55 **2451**

Survey of Radio-Frequency Resistors with Kilowatt Ratings.—D. R. Crosby. (*RCA Rev.*, Dec. 1951, Vol. 12, No. 4, pp. 754–763.) Discussion of design and operating characteristics of resistors used for communication and r.f.-heating equipment in the frequency range 300 kc/s–30 Mc/s. Resistance values may be from a few tenths of an ohm to about 600 Ω, and the power range is 5–100 kW. The three basic types used are metal-wire, carbon-film and water-column resistors.

621.316.842(083.74) **2452**

A Design for Standard Resistance Coils.—C. R. Barber, A. Gridley & J. A. Hall. (*J. sci. Instrum.*, March 1952, Vol. 29, No. 3, pp. 65–69.) Details are given of a method of construction specially suitable for resistance coils used in bridges. A strain-free helix of minalpha (manganin) wire is supported in a spiral groove cut in a perspex disk, and hermetically sealed between perspex cover plates. The heat treatment of the wire to obtain good stability is described. Coils of 1 000 Ω resistance, made from about 42 m of 0·006-in. wire, showed a rise of resistance of the order of 2 parts per million per month during the first few months after winding.

621.316.87 : 541.18 : 537.311.35 **2453**

Polaresistivity and Polaristors.—Hollmann. (See 2538.)

621.318.42.018.78 **2454**

Harmonic and Combination Oscillations in Ferromagnetic Materials.—G. Hoffmann. (*Arch. elekt. Übertragung*, March 1952, Vol. 6, No. 3, pp. 99–108.) Distortion effects at very low frequencies in coils with ferromagnetic cores are investigated theoretically, particularly for the case of simultaneous excitation by two sinusoidally varying fields of different frequencies. The relation between the complex-permeability curve and the combination frequencies is derived for the Rayleigh region (where the branches of the hysteresis loop are parabolic). For magnetically stable (carbon-free) materials the calculated values are well supported by measured values over a wide range. For magnetically unstable materials, the calculation provides, in conjunction with distortion measurements, a possible method of investigating the creep effect.

621.392 **2455**

Introduction to Formal Realizability Theory: Part 2.—B. McMillan. (*Bell Syst. tech. J.*, May 1952, Vol. 31, No. 3, pp. 541–600.) Discussion of conditions to be satisfied for a network to realize a given positive real impedance matrix. Part 1: 2138 of August.

621.392 **2456**

The Synthesis of RC Networks to have Prescribed Transfer Functions.—H. J. Orchard. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 725–726.) Discussion on 2371 of 1951.

621.392.5 **2457**

The Iterated Network and its Application to Differentiators.—M. C. Pease. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 709–711.) A compact and convenient expression is derived for the transmission matrix of any iterated structure, in terms of the number of units in the structure and of the transmission matrix of the unit element. The expression is used for analysis of the operation of an iterated RC differentiating network, which is shown to have an effective time constant much less than that of the unit element.

621.392.5 **2458**

Image Impedances of Active Linear Four-Terminal Networks.—H. Sutcliffe. (*Wireless Engr*, June 1952, Vol. 29, No. 345, pp. 169–170.) A matrix treatment showing that the formula expressing the image impedance of a passive quadripole in terms of open-circuit input impedance and short-circuit admittance applies to an active linear network.

621.392.5 **2459**

The Gyrator.—G. W. O. H. (*Wireless Engr*, June 1952, Vol. 29, No. 345, pp. 143–145.) Comment, with further analysis, on the special 4-terminal network conceived by Tellegen. See 301 of 1951 and back references.

621.392.5 **2460**

Operational Analysis of Variable-Delay Systems.—L. A. Zadeh. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 564–568.) The output of a variable-delay system is related to its input by a delay operator which has the usual exponential form, but differs from conventional (time-invariant) delay operators in that the time delay is a function of time. Systems in which the variation of delay is due to motion of the receiver (R) or source (S) or both (RS) are analysed in general terms. An operational relation is obtained for the correlation function of the output of a type-R system, and is applied to the determination of the correlation function of a f.m. sound wave.

621.392.5 : 517.56 **2461**

The Approximation with Rational Functions of Prescribed Magnitude and Phase Characteristics.—J. G. Linvill. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 711–721.) A method of successive approximations is applied to the selection of network functions having desired magnitude and phase variation with frequency. Adjustment of the magnitude and phase characteristics is effected simultaneously.

621.392.5 : 534.321.9 : 534.133 **2462**

Performance of Ultrasonic Vitreous-Silica Delay Lines.—M. D. Fagen. (*Tele-Tech*, March 1952, Vol. 11, No. 3, pp. 43–45 . . 144.) The electrical performance of an ultrasonic delay line is analysed in terms of its equivalent circuit; insertion loss and bandwidth are investigated in relation to the parameters of the piezoelectric transducer, the acoustic medium and the electrical termination. Results of tests at 10 and 60 Mc/s and with resistive terminations of 75 to 1 000 Ω are shown. With low terminal impedance a large bandwidth is obtained but insertion loss is relatively high.

621.392.52 **2463**

Electrical Separating Networks with Series-Resonance Circuits as Blocking Elements.—R. Becker. (*Telefunken Ztg*, March 1952, Vol. 25, No. 94, pp. 33–40.) Discussion of devices enabling a single aerial to be used with two transmitters or receivers simultaneously, or with a transmitter and a receiver. General design formulae are derived and applied to the design of a unit for use with two 1-kW transmitters with frequencies of 46·4 and

49·1 Mc/s respectively. Calculated values of attenuation for the two frequencies were in good agreement with measured values (~93 db) for practical equipment, which is described. The construction is also described of a transmitter-receiver type for the range 45–75 Mc/s and of a low-power unit for beam R/T on 80 Mc/s.

621.392.52 **2464**

On the Theory of Filtration of Signals.—L. A. Zadeh. (*Z. angew. Math. Phys.*, 15th March 1952, Vol. 3, No. 2, pp. 149–156. In English.) An outline of the theory of linear variable filters. See also 2147 of August.

621.392.52 **2465**

Theory of Transmission Time and Build-Up Time in Electrical Filters with Phase Distortion.—T. Laurent. (*Arch. elekt. Übertragung*, March 1952, Vol. 6, No. 3, pp. 91–98.) The theory is based on the frequency-transformation method developed previously (471 of 1937). New definitions of transmission time and build-up time are derived which are valid for filters with phase distortion and which enable values to be calculated easily from attenuation and phase shift.

621.392.52.015.7 **2466**

Pulsed Circuits. Transmission Function. Problem of Isomorphic Transmission.—H. Borg. (*Ann. Télécommun.*, March 1952, Vol. 7, No. 3, pp. 115–126.) A definition of an ideal filter, based on the symbolic expression for the transient response of a passive linear system, implies certain conditions of amplitude, phase and pass band. Echo phenomena in actual filters are studied by different series developments of the transmission function and by analysis based on Laplace transforms. An analytical expression for the transmission characteristic of a passive circuit is derived in terms of pulse amplitude, duration and delay time; this determines the conditions under which no alteration of the pulse shape occurs. 39 references.

621.392.54.012.3 : 621.392.26 **2467**

Chart for the TE_{11} Mode Piston Attenuator.—C. M. Allred. (*Bur. Stand. J. Res.*, Feb. 1952, Vol. 48, No. 2, pp. 109–110.) An abac for determination of attenuation as dependent on frequency and on conductivity and radius of a cylindrical-waveguide attenuator.

621.395.645 : 621.395.97 **2468**

Radio-Diffusion Amplifiers for Standard [telephone] Circuits.—J. Jacot. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, 1st March 1952, Vol. 30, No. 3, pp. 81–87. In French.) Developments in Switzerland up to 1938 are reviewed and descriptions are given of two types of amplifier designed to meet C.C.I.F. requirements for programme transmission on standard telephone circuits. The two types are similar in principle, both having two coupled stages, the essential difference being in the feedback circuit used to correct the gain for the very low and the high frequencies.

621.395.661.1 **2469**

Study of, Tests on, and Suggestions for Acceptance Standards for Repeater Coils used on Lines for Musical-Programme Transmission.—R. Salvadorini. (*Poste e Telecomunicazioni*, March 1952, Vol. 20, No. 3, pp. 115–130.) The characteristics of repeater coils are examined, and results of tests on six samples reported. Minimum performance requirements in respect of insulation, distortion, losses, frequency characteristics, transients, crosstalk, and d.c. tests are listed, as a basis for acceptance standards.

621.396.611.1 **2470**

Free Oscillations in *n*-Mesh Networks with Varying Parameters.—W. Haacke. (*Arch. elekt. Übertragung*, March 1952, Vol. 6, No. 3, pp. 114–119.) The system is represented by a matrix of n linear second-order differential equations with periodically varying coefficients; the individual equations are separated by a linear transformation and solved by Erdélyi's method (1934 Abstracts, p. 436), and the complete solution is obtained by combining the individual solutions. Circuits with capacitances varying periodically about a mean value are mainly considered; the calculation is similar for the case of varying inductances. The analysis applies only to cases where all the parameter variations obey the same law. Where the solutions of any of the n equations are unstable, the corresponding fundamental frequencies may disappear completely, to be replaced by multiples of half the variation frequency.

621.396.611.1 : 517.51 **2471**

Resonant Circuit with Periodically Varying Parameters.—P. Bura & D. M. Tombs. (*Wireless Engr*, April & May 1952, Vol. 29, Nos. 343 & 344, pp. 95–100 & 120–126.) Theoretical and experimental investigation of the circuit with periodically varying resistance. The variation is achieved by applying a voltage of given frequency to the grid of a dynatron, thus varying the magnitude of the negative resistance which the dynatron presents to the oscillatory circuit. A steady-state solution of Mathieu's equation is obtained by means of integral equations, and for the oscillatory regime a solution of an extended Hill's equation is obtained by a method similar to that of Ince. The steady-state response to an applied alternating voltage, of frequency approximately the same as the resonance frequency, exhibits multiple-resonance effects, each maximum corresponding to detuning equal to an integral multiple of the frequency of the resistance variation. As in the case of oscillation excitation by variation of inductance or capacitance, the frequency at which oscillations are most easily excited by resistance variation is double the resonance frequency of the circuit. If the alternating voltage applied to the dynatron grid is increased gradually from zero, at a certain critical voltage oscillations suddenly commence, with frequency exactly half that of the grid voltage, even if the circuit is detuned. Experimental results are shown graphically.

621.396.611.21.029.3 **2472**

Quartz Vibrators for Audio Frequencies.—J. E. Thwaites. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 158–159.) Summary only. Results obtained for silver-plated wire-mounted +5° X-cut bars show that the frequency f of flexural vibrations is given by the formula $f = 5\,740\, w/l^2$, where f is in kc/s and w and l are respectively the width and length of the bar in mm. The frequency/temperature characteristics of such bars are approximately parabolic, with a vertex of maximum frequency at some temperature between —10° and +50°C, depending on the value of w/l. For bars of ring form with a small gap, $f = 4\,350\, w/l^2$, where w is the width in the plane of flexure and l is the mean arc length. Approximate relations between dimensions, frequency and temperature are shown graphically for straight bars and for gapped rings. Both types have two nodes and can be supported by four wires in a glass envelope. In straight bars the distance of the nodes from each end is $0{\cdot}224\, l$; in gapped rings the nodes subtend an angle of 66° at the centre of curvature. A simple method of determining the parameters of the equivalent circuit for such vibrators is described.

621.396.611.39 : 621.392.26 **2473**

Microwave Coupling by Large Apertures.—S. B. Cohn. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 696–699.) A frequency-correction factor is proposed for Bethe's small-aperture coupling relation for a transverse diaphragm in a rectangular waveguide. Experimental results for apertures of many different shapes and sizes show this correction factor to be accurate up to slightly above the resonance frequency of each aperture. Approximate formulae are given for the resonance length of a narrow rectangular aperture and for the Q of a resonant iris loaded by matched waveguide. The effect of wall thickness is also considered.

621.396.615.001.8 **2474**

The Action of Locked Oscillators.—E. Roessler. (*Fernmeldetech. Z.*, March 1952, Vol. 5, No. 3, pp. 97–100.) Fixing of the starting point of oscillations by means of a locked oscillator is used at present for three purposes: (*a*) for the suppression of transmitter noise in multichannel p.ph.m. transmission on dm-wave links, (*b*) for the suppression of receiver noise in super-regenerative reception, (*c*) for the production of a phase-related pulse for utilizing the Doppler effect in radar measurements. The action of the locked oscillator in these three cases is explained and further possible applications are considered.

621.396.615.029.3 : 621.396.621.53 **2475**

Beat-Frequency Tone Source. Mathematical Theory of Mixing.—C. G. Mayo. (*Wireless Engr*, June 1952, Vol. 29, No. 345, pp. 148–155.) Three systems of mixing are discussed: (*a*) multiplication in a square-law device, (*b*) addition followed by linear rectification, (*c*) addition of one component to a square wave synchronous with the other component, followed by linear rectification. Method (*c*) is analysed in detail and the distortion likely to occur in practical circuits is evaluated. With regard to output, distortion and noise, method (*c*) is by far the best.

621.396.615.17 **2476**

Production of Very Short Pulses by means of a Pulse-Excited Oscillatory Circuit Shunted by a Germanium Crystal.—H. Mayer. (*C. R. Acad. Sci., Paris*, 10th March 1952, Vol. 234, No. 11, pp. 1131–1133.) The circuit described by Reiffel (2375 of 1951) is adapted for actuation by pulses from a multivibrator. The optimum operating conditions are calculated and a comparison is made between theoretical and experimental results.

621.396.615.17 : 621.3.087.4 : 551.510.535 **2477**

A Timebase Circuit for a High-Precision Ionospheric Sounding Apparatus.—B. M. Banerjee & R. Roy. (*Indian J. Phys.*, Sept. 1950, Vol. 24, No. 9, pp. 411–419.) Description of a circuit which produces a 10-line raster on the screen of the c.r.o. Each line of the raster takes 333 μs, a time which corresponds to 50 km of ionosphere height. Marker pips indicate 5-km intervals and an intensifying pulse is applied to any one of the ten lines selected by an adjustable trigger circuit. Fully detailed circuit diagrams of the different units of the equipment are given.

621.396.615.17 : 621.396.615.141.2 **2478**

Magnetron Harmonics at Millimeter Wavelengths.—J. A. Klein, J. H. N. Loubser, A. H. Nethercot, Jr, & C. H. Townes. (*Rev. sci. Instrum.*, Feb. 1952, Vol. 23, No. 2, pp. 78–82.) Harmonics present in the output of magnetrons are isolated (*a*) by using a tapered waveguide section to cut off at wavelengths shorter than the fundamental, (*b*) by using a diffraction grating. A Golay cell or a Si-crystal rectifier is used as detector. The tenth harmonic ($\lambda = 1\cdot25$ mm) has been obtained from K-band valves and the third harmonic ($\lambda = 1\cdot1$ mm) from 3·3-mm valves, with an estimated peak power of a few hundred microwatts. Data are included on the harmonic spectra of various types of magnetron.

621.396.616.015.7 : 621.316.546 **2479**

Nonelectronic Rectangular-Wave Generator.—B Bederson & M. Silver. (*Rev. sci. Instrum.*, March 1952, Vol. 23, No. 3, p. 133.) A circuit including a mercury relay tube in series with d.c. supply and resistive load produces square pulses of peak power 250 W and duration from 10 ms to 2·5 sec.

621.396.645 **2480**

Cathode-Coupled Amplifier.—I. F. Macdiarmid. (*Wireless Engr*, June 1952, Vol. 29, No. 345, p. 169.) Discussion on 1559 of June (Lyddiard). An alternative equivalent circuit and convenient method of calculating harmonic distortion are described.

621.396.645 **2481**

Cathode-Follower Operation.—A. J. Shimmins. (*Wireless Engr*, June 1952, Vol. 29, No. 345, pp. 155–163.) The response of cathode-follower circuits to pulse and sawtooth signals has been considered previously (846 of 1951). Three methods of improving the transient and steady-state performance of cathode-follower circuits with a capacitive load are studied: (*a*) simple series-inductance compensation, (*b*) use of a low-pass filter as the cathode load, (*c*) increase of the capacitance between grid and cathode. Method (*a*) offers considerable advantages; an inductance value of $0\cdot5\,C_L R_0^2$ is found suitable, where C_L is the load capacitance and R_c the output impedance.

621.396.645 **2482**

Amplifier Frequency Response.—D. A. Bell. (*Wireless Engr*, May 1952, Vol. 29, No. 344, pp. 118–119.) Discussion of the effect of feedback, including consideration of (*a*) faults that cannot be corrected by use of feedback, (*b*) cases in which the desired result can be achieved equally well by other means.

621.396.645 : 621.396.822 **2483**

Background Noise in Amplifiers — Its Reduction — Application in Physiology.—B. Bladier. (*Acustica*, 1952, Vol. 2, No. 1, pp. 23–24. In French.) Experiments with a 1–200-c/s amplifier for encephalography showed that the background noise consisted mainly of thermal agitation noise in the input resistance and in the load resistance of the first valve, with a smaller contribution due to shot effect. By reducing the input resistance and using a diode as the load resistance, the noise was reduced by two thirds. Type-4673 and Type-1603 valves were found to be best suited for the particular purpose.

621.396.645.018.7 **2484**

Distortion of N-Shaped Signals in RC Amplifiers.—H. Oertel. (*Funk u. Ton*, March 1952, Vol. 6, No. 3, pp. 123–129.) Analysis indicating that with a single-stage amplifier, less than 10% distortion of an N-shaped pulse is only to be expected when $\omega_u . T < 0\cdot1$ and $\omega_0 . T > 100$, T being the signal duration and ω_u and ω_0 the angular velocities corresponding to the lower and upper limiting frequencies respectively.

621.396.645.029.3 **2485**

High-Quality Amplifier Modifications.—D. T. N. Williamson. (*Wireless World*, May 1952, Vol. 58, No. 5, pp. 173–176.) Describes how the original circuit (3101 of 1949) should be modified for use with long-playing records, and gives details of circuit changes necessary for the direct connection of high-impedance pickups. Published articles will be reprinted in a revised edition of the Williamson Amplifier booklet.

621.396.822 : 621.396.615 : 529.786 **2486**

Effect of Background Noise on the Frequency of Valve Oscillators.—A. Blaquière. (*C. R. Acad. Sci., Paris,* 10th March 1952, Vol. 234, No. 11, pp. 1140–1142.) In most practical cases the primary changes of phase and amplitude produced by noise pulses (see 2162 of August) are accompanied by a secondary effect due to the dependence of oscillation frequency on amplitude; the frequency fluctuation is related to noise power. The magnitude of this secondary effect is the best criterion of quality of an electronic clock. The extension of Nyquist's theory previously developed (335 of February) is used to classify oscillators from this point of view.

GENERAL PHYSICS

535.42 : 538.566 **2487**

Huyghens' Principle in Diffraction Problems.—J. P. Schouten & A. T. de Hoop. (*Tijdschr. ned. Radiogenoot.*, March 1952, Vol. 17, No. 2, pp. 45–62.) Using a method due to Clavier (*Elect. Commun.*, 1948, Vol. 25, p. 148), Huyghens' Principle is derived directly from Maxwell's equations, without introducing fictitious magnetic charges and currents. In the limiting case when the surface over which the integration is extended is an infinite plane, the expressions obtained coincide with those derived by Bethe (706 of 1945) and Smythe (*Phys. Rev.*, 1947, Vol. 72, p. 1066).

537.311.31 **2488**

On the Theory of Electrical Conductivities of Monovalent Metals.—A. B. Bhatia. (*Proc. phys. Soc.*, 1st March 1952, Vol. 65, No. 387A, pp. 188–191.)

538.221 **2489**

Some Magnetic Properties of Metals: Part 1 — General Introduction, and Properties of Large Systems of Electrons.—R. B. Dingle. (*Proc. roy. Soc. A.*, 20th March 1952, Vol. 211, No. 1107, pp. 500–516.) The Schrödinger equation is solved for an unbounded system, and the limiting case of a system much larger than the electronic orbits is considered. Expressions for the density of states and the free energy of the system are derived, and the magnetic susceptibility is evaluated assuming the thermodynamic potential per electron is constant. Explicit formulae are given for the temperature dependence of the field-independent term in the susceptibility. Corrections for electron spin are applied to the results obtained.

538.221 **2490**

Some Magnetic Properties of Metals: Part 2 — The Influence of Collisions on the Magnetic Behaviour of Large Systems.—R. B. Dingle. (*Proc. roy. Soc. A.*, 20th March 1952, Vol. 211, No. 1107, pp. 517–525.) "A discussion of the effect of collisions on the magnetic properties of a large system of free electrons shows that the non-periodic term in the susceptibility is hardly affected, but that the periodic terms are reduced in magnitude by a factor exp $(—hp/\tau\beta H)$, where p is the harmonic considered, τ is the mean collision time, and $\beta = eh/2\pi mc$."

538.521 **2491**

Effect of Torsion on a Longitudinally-Magnetized Iron Wire.—G. W. O. H. (*Wireless Engr*, May 1952, Vol. 29, No. 344, pp. 115–117.) An account of effects observed by W. V. Dromgoole, New Zealand. An e.m.f. is induced in a ferromagnetic wire on twisting one end of it in an alternating axial magnetic field, due to the circular component of the alternating magnetic flux; the e.m.f. depends on the angle of twist and the permeability of the material and is large over the frequency range 300 c/s to 20 kc/s. Several practical applications are suggested.

538.569.4 **2492**

On the Absorption of U.H.F. Radio Waves by Opalescent Binary Liquid Mixtures.—A. Choudhury. (*Indian J. Phys.*, Nov. 1950, Vol. 24, No. 11, pp. 507–512.) Investigations of nitrobenzene-hexane and aniline-cyclohexane mixtures in the range 300–510 Mc/s show that in both cases a new absorption peak appears on the l.f. side of the peak found for one of the pure constituents having polar molecules, the original peak being much reduced.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.5 : 621.396.9 **2493**

Characteristics of Radio Echoes from Meteor Trails: Part 3 — The Behaviour of the Electron Trails after Formation.—J. S. Greenhow. (*Proc. phys. Soc.*, 1st March 1952, Vol. 65, No. 387B, pp. 169–181.) It is suggested that long-duration meteor echoes are due to reflection from trails with very high electron density. Further evidence is adduced to show that the amplitude fluctuations observed are caused by the influence of atmospheric turbulence on the meteor trail. Winds with velocities of the order of 20 m/s at heights between 80 and 100 km are inferred. See also 2782 of 1948 (Lovell & Clegg) and 359 of 1951 (Greenhow).

523.72 : 539.1 **2494**

Emission of Corpuscles from the Sun.—K. O. Kiepenheuer. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 113–120.) Arguments in favour of the existence of solar corpuscles are reviewed and the geomagnetic action of such particles is analysed. The streams producing moderate disturbances of the earth's magnetic field are identified with invisible extensions of the solar streamers.

523.746 "1951.10/.12" **2495**

Provisional Sunspot-Numbers for October to December 1951.—M. Waldmeier. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 138.) See also *Z. Met.*, Feb. 1952, Vol. 6, No. 2, p. 58.

523.78 : 621.396.11 **2496**

Effect of the Annular Eclipse of March 7, 1951, on Radio-Wave Propagation.—(See 2575.)

523.8 : 621.396.822 **2497**

A New Radio Interferometer and its Application to the Observation of Weak Radio Stars.—M. Ryle. (*Proc. roy. Soc. A.*, 6th March 1952, Vol. 211, No. 1106, pp. 351–375.) The reception pattern of a pair of in-phase spaced aerials is A_1 (θ). If a $\lambda/2$ length of feeder is inserted in the line to one of them the pattern, in which the maxima and minima are interchanged, becomes $A_2(\theta)$. A switch changes the pattern rapidly from A_1 to A_2 so that the output contains an alternating component which is proportional to $(A_1 - A_2)$ and to the power flux received from a point source. An amplifier discriminates in favour of the alternating component and allows the output due to a point source to be observed without interference from steady sources or random noise. The method can be used for the detection of weak point sources but has other important advantages, including high accuracy of position finding.

550.372 : 551.311.234.5 : 621.3.029.62 **2498**

The Electrical Constants of Soil at Ultra-High Frequencies.—P. M. Sundaram. (*Indian J. Phys.*, Nov. 1950, Vol. 24, No. 11, pp. 469–478.) A Lecher-wire system, completely buried in the soil for an adjustable length, was used to investigate the variation of the dielectric constant κ and conductivity σ of a clay soil as a function of frequency (43–74 Mc/s), sand admixture and moisture content. Results are shown in tables and curves. A peak in the curves for κ occurs at about 47 Mc/s. At all the frequencies used, κ increases with moisture content up to 10% or 12% and then decreases. A maximum value of σ was found for moisture content of 8–10%.

550.38 **2499**

The Earth's Magnetism and its Changes.—S. Chapman. (*Proc. Indian Ass. Cult. Sci.*, 1950, Vol. 33, 16 pp.; *Indian J. Phys.*, Sept. 1950, Vol. 24, No. 9, 16-page insert between pp. 420 and 421.) Text of Ripon Professorship Lecture, Calcutta, January 1949, reviewing present knowledge and discussing various theories.

550.38 : 523.75 : 551.510.535 **2500**

Characteristics of the Solar Flare Effect (Sqa) on Geomagnetic Field at Huancayo (Peru) and at Kakioka (Japan).—T. Nagata. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 1–14.) The transient characteristics of the geomagnetic-field variations due to solar-flare effects are examined statistically, taking into account induction effects in the ionosphere and in the earth. An estimated value of 6–7 × 10^{-8} e.m.u. is found for the integrated conductivity of the ionosphere over Huancayo, Kakioka and Watheroo.

550.38 "1951.07/.09" **2501**

International Data on Magnetic Disturbances, Third Quarter, 1951.—J. Bartels & J. Veldkamp. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 135–137.)

550.38 "1951.10/.12" **2502**

Cheltenham [Maryland] Three-Hour-Range Indices *K* for October to December, 1951.—R. R. Bodle. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, p. 138.)

550.384/.385 **2503**

Geomagnetic Field Variations at Kodaikanal.—M. V. Sivaramakrishnan. (*Nature, Lond.*, 8th March 1952, Vol. 169, No. 4297, pp. 409–410.) Anomalies in sudden commencements, and geomagnetic effects of solar flares, are reported for the period 1949–1951.

550.385 **2504**

On the Theory of the First Phase of a Geomagnetic Storm: a New Illustrative Calculation based on an Idealised (Plane not Cylindrical) Model Field Distribution.—V. C. A. Ferraro. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 15–49.) Extension of discussion presented previously by Chapman & Ferraro (14 of 1941).

550.385 "1951.07/.12" **2505**

Principal Magnetic Storms [July–Dec. 1951].—(*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 139–141.)

551.510.3 **2506**

The Pressure, Density, and Temperature of the Earth's Atmosphere to 160 Kilometers.—R. J. Havens, R. T. Koll & H. E. LaGow. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 59–72.) From rocket measurements made at White Sands, New Mexico, and at the equator the following values are deduced: pressure at 160 km, 2 × 10^{-6} mm Hg; density at 160 km, 1·5 × 10^{-6} g/m³; temperature passes through a maximum of 270°K at 50 km and a minimum of 190°K at 80 km, increasing to about 500°K at 160 km.

551.510.535 **2507**

Limitations on the Calculation of Expected Virtual Height for Specific Ionospheric Distributions.—J. Shmoys. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 95–111.) Virtual height is defined (*a*) on a geometrical-optics basis and (*b*) in terms of the frequency derivative of the phase of the reflection coefficient; the former definition can be derived from the latter by use of the phase-integral method. The two definitions are compared for the cases of linear, rectangular, Epstein and parabolic charge distributions. When the reflected wave contains more than one pulse the relation between virtual height and frequency derivative of phase is not valid; in this case the frequency derivative of phase cannot be interpreted as the time delay of any one of the pulses.

551.510.535 **2508**

The Reflection Coefficient of the Exponential Layer.—J. Shmoys. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 142–143.) Discussion on 132 of January (Mitra).

551.510.535 **2509**

Movements of the Sporadic-E Layer of the Ionosphere.—N. C. Gerson. (*Z. angew. Phys.*, March 1952, Vol. 4, No. 3, pp. 81–82.) Report of observations made in North America on 16th and 17th June 1949. Mean drift velocities of 130 and 300 km/hr were deduced. See also 2426 and 2998 of 1951.

551.510.535 : 525.624 **2510**

Tides in the Ionosphere.—A. P. Mitra. (*Indian J. Phys.*, Sept. 1950, Vol. 24, No. 9, pp. 387–404.) A connected account of the results of various recent investigations, both theoretical and experimental, of tidal effects in the ionosphere, and discussion of Martyn's electrodynamic theory of such effects. Results of observations at Calcutta, Delhi and Chunking during 1946–1948 are presented; the curves showing the average diurnal variations of the height of the F_2 layer have two maxima, one about noon and the other about midnight.

551.510.535 : 551.594.5 **2511**

The Association of Absorption and E_s Ionization with Aurora at High Latitudes.—J. P. Heppner, E. C. Byrne & A. E. Belon. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 121–134.) An analysis based on the coexisting auroral conditions is made of nocturnal E_s ionization and 'no echo' occurrences as observed from *h′f* records obtained at College, Alaska, during the period 8th Sept. 1950–16th April 1951. In general, (*a*) E_s ionization increases at successively greater heights as aurora approaches the zenith from the north; (*b*) in the presence of different non-pulsating auroral forms the E_s ionization varies with changes in auroral form in the same way as luminosity varies, and variations in the height of maximum ionization follow variations in auroral height; (*c*) complete absorption is only slightly more frequent during non-pulsating aurora than during absence of aurora, but prevails in the presence of pulsating aurora. Geomagnetic influences are discussed.

LOCATION AND AIDS TO NAVIGATION

621.396.9 **2512**

Technique for Measurement of Radar Characteristics of Targets.—R. G. Peters. (*TV Engng, N.Y.*, Dec. 1951, Vol. 2, No. 12, pp. 10–11 & Jan. 1952, Vol. 3, No. 1, pp. 26–27.) Description of a method using models, the reflections from which cause unbalance of a hybrid junction in the waveguide feeding a horn aerial, the amount of unbalance being a function of the echoing area of the model. A 9·8-kMc/s frequency-stabilized transmitter was used, and balance stability was improved by constructing the hybrid junction and horn of invar. Suitable suspension arrangements for the models were determined by experiment. Calibration was effected by use of spheres, of diameter ranging from 5 in. to 10 in.

621.396.9 : [523.7 + 523.4 **2513**

On the Possibility of obtaining Radar Echoes from the Sun and Planets.—F. J. Kerr. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 660–666.)

621.396.9 : 621.396.8 **2514**

Fluctuations of Ground-Clutter Return in Airborne Radar.—T. S. George. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 160–161.) Summary only. Two types of fluctuations are analysed: that in a single-range sweep at fixed azimuth where clutter is assumed to be due to a large number of small reflectors randomly situated on the ground, and that which occurs between video pulses at the same range due to the relative motion of the aircraft and ground.

621.396.932/.933].1 + 621.396.97 **2515**

Common-Wave Broadcasting and Hyperbolic Navigation.—M. Pohontsch. (*Telefunken Ztg*, March 1952, Vol. 25, No. 94, pp. 27–32.) Discussion of the connection between the problems of frequency control of common-wave transmitters and those of Decca and similar navigation systems. To be continued.

621.396.932.2 **2516**

Requirements for Modern Radio Direction Finders and Means for their Fulfilment.—W. E. Steidle. (*Telefunken Ztg*, March 1952, Vol. 25, No. 94, pp. 12–15.) Discussion of sensitivity and sharpness of direction indication, with comparison results for Telefunken ship equipment used with different aerial systems. The use of an iron-cored goniometer in conjunction with a high-gain superheterodyne receiver has increased the sensitivity of the Telegon d.f. equipment, using crossed screened frame coils of area 0·95 m², up to that of equipment on the German hydrographic survey vessel *Gauss*, which used crossed stretched-wire loops of area 9 and 52 m² respectively.

621.396.932.2 : 621.396.677.5 **2517**

Comparison between Frame-Coil and Stretched-Wire-Loop Aerials for Ship Direction Finders.—H. Gabler, G. Gresky & W. Runge. (*Telefunken Ztg*, March 1952, Vol. 25, No. 94, pp. 5–11.) Measurements showed that when using the Telegon direction finder with its crossed coils of area 0·95 m², the width of the minimum was 2·4 times greater than with stretched-wire loops of area about 9 m². The direction-finding sensitivity of the Telegon equipment was found equal to that of goniometer direction finders using stretched-wire loops of area about 10 m². Theoretical investigations of the effect of the geometry and electrical data of a coil on the sharpness of the d.f. indication were confirmed experimentally.

621.396.933 **2518**

An Aided Layer for Shoran.—R. C. Richardson. (*Aust. J. appl. Sci.*, March 1952, Vol. 3, No. 1, pp. 16–24.) Description of a unit in which a motor, whose speed is controlled through a velodyne [962 of 1948 (Williams & Uttley)] by rotation of the shoran handwheel, is geared differentially to the handwheel shaft and thus facilitates its rotation when the range is varying rapidly. The output drive from the unit to the display and other associated units is through an Admiralty M-type electrical transmission system.

621.396.933.2 : 621.396.677.6 **2519**

Recent Developments in Short-Wave Adcock Direction Finders.—A. Troost. (*Telefunken Ztg*, March 1952, Vol. 25, No. 94, pp. 16–27.) The relative merits of U-type and H-type aerials are discussed. For transportable equipment U-type aerials are preferable. Systematic errors can be reduced by increasing the number of aerials used; this also results in increased sensitivity. Subdivision of aerials gives improvement as regards night effect, suppression of resonance errors, and a cosine type of vertical characteristic for single aerials throughout the frequency range. A six-mast system is considered the best. With eight or more masts the slight increase of sensitivity is offset by increased liability to polarization and resonance errors. A description is given of equipment using six 8·5-m telescopic masts at the corners of a hexagon 8 m across. The goniometer is of the iron-ring type with e.s. screen. The use of a push-pull wide-band amplifier gives a sensitivity of 0·15–0·3 μV/m, depending on the frequency, the range covered in four bands being 4·5–25 Mc/s.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788 : 541.56 **2520**

The Measurement of Extremely Low Pressures below 10^{-7} mm Hg by means of an Adsorption Manometer.—M. Seddig & G. Haase. (*Z. angew. Phys.*, March 1952, Vol. 4, No. 3, pp. 105–108.) Description of an experimental procedure by which pressure changes after gettering and sealing off are determined from the slope of the work-function time characteristic of a purified tungsten emitting surface in the evacuated space. The work function is determined by photoelectric measurement.

533.5 **2521**

The Production of Very High Vacua by the use of Getters.—S. Wagener. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 135–147.) "The characteristics of getters are defined and correlations between them are derived. Methods for measuring the characteristics are described and values of these for different getters and gases are given. Two main mechanisms of the gettering process are distinguished, namely contact gettering and discharge gettering, of which the latter, on account of the higher gettering rates attainable, is found to be of chief importance for the production of very high vacua. The processes contributing to discharge gettering are investigated in detail, and an attempt is made to determine the parts played by adsorption, diffusion and chemical reaction in different systems of getters and gases. The efficiency of flash getters is compared with that of coating getters, particularly thorium. It is found that gases like oxygen and carbon dioxide are taken up irreversibly during discharge gettering with thorium. The pressures attainable in valves using flash and coating getters are measured, and the influence of some parameters such as baking time on the pump or pressure during sealing-off is investigated."

535.215.4 : 537.311.33 : 546.86 **2522**

Properties of Films of Non-Metallic Antimony.—T. S. Moss. (*Proc. phys. Soc.*, 1st Feb. 1952, Vol. 65, No. 386A, pp. 147–148.) Consideration of the periodic table of elements in the light of recent investigations of photoconductivity indicates that there should be a semiconducting form of Sb with activation energy between 0·37 and 0·1 eV and with photoconductive properties for wavelengths near 8 μ. Such layers were obtained experimentally by evaporation on to substrates at 195°K or 90°K. Resistance/reciprocal-temperature and sensitivity/wavelength curves obtained from measurements are shown.

537.226 : 621.396.677 **2523**

Isotropic Artificial Dielectric.—R. W. Corkum. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 574–587.) Theoretical and experimental investigations of media consisting of a cubic lattice of metal or dielectric spheres are described. Expressions are derived for the index of refraction, dielectric constant, and magnetic

F. Conrad. (*Frequenz*, March 1952, Vol. 6, No. 3, p. 88.) Two graphs show comparisons between the time markings of the FuA standard-frequency equipment (Rohde & Schwarz quartz clock) with GBR, GIC and WWV signals and with the transmissions from the Hydrographic Institute, Hamburg, and from München-Ismaning.

621.317.3 : 621.396.611.21 **2549**

A Simple Method of Measurement of Quartz Crystal Characteristics.—J. Coulon. (*C. R. Acad. Sci., Paris*, 17th March 1952, Vol. 234, No. 12, pp. 1269–1271.) The equivalent-circuit parameters of the crystal are found from (*a*) the curve for the variation of oscillator frequency with variation of a control capacitance in series with the crystal, (*b*) the curve for the voltage at the oscillator valve grid, (*c*) a capacitance measurement and (*d*) an impedance measurement. The circle diagram introduced previously (2550 below) is used.

621.317.3 : 621.396.611.21 **2550**

Plotting the Resonance Curve of a Piezoelectric Quartz Crystal, using a Circle Diagram.—J. Coulon. (*C. R. Acad. Sci., Paris*, 10th March 1952, Vol. 234, No. 11, pp. 1138–1140.) The plotting of the resonance curve is facilitated by constructing a circle diagram whose coordinates are related to the parameters of the equivalent circuit of the crystal.

621.317.3 : 621.396.65 **2551**

Measuring Techniques for Broad-Band, Long-Distance Radio Relay Systems.—W. J. Albersheim. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 548–551.) Methods are outlined for investigation of (*a*) the transient response of the system to step voltages or square waves, (*b*) the frequency characteristics of gain, phase, impedance, and their frequency derivatives, (*c*) the amplitude characteristics of output nonlinearity and of intermodulation products.

621.317.31/.32]. 029.3 : 537.324 **2552**

Thermal Converters as A.C.-D.C. Transfer Standards for Current and Voltage Measurements at Audio Frequencies.—F. L. Hermach. (*Bur. Stand. J. Res.*, Feb. 1952, Vol. 48, No. 2, pp. 121–128.) An account of thermoelements and associated equipment used at the National Bureau of Standards primarily for the standardization of a.c. ammeters and voltmeters submitted for test. An accuracy to within 0·01% in the a.c.-d.c. transfer can be achieved for currents of 1 mA–50 A and voltages of 0·2–750 V at frequencies from 25 c/s to 20 kc/s. Factors limiting the transfer accuracy are analysed and approximate solutions are given of nonlinear differential equations governing the heating of a conductor by an electric current.

621.317.324(083.74) **2553**

Development of V.H.F. Field-Intensity Standards.—F. M. Greene & M. Solow. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, p. 573.) Abstract of U.R.S.I.-I.R.E. Meeting paper, Washington, 1949. See 3090 of 1950.

621.317.336 : 621.315.212 **2554**

Reflections in a Coaxial Cable due to Impedance Irregularities.—G. Fuchs. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 161–164.) Summary only. Theoretical relations between impedance irregularities, input-impedance deviation and pulse echo are derived and experiments are described which confirm the theory.

621.317.42 **2555**

A New Device for Measuring the Strength of a Magnetic Field.—R. Birebent. (*C. R. Acad. Sci., Paris*, 10th March 1952, Vol. 234, No. 11, pp. 1135–1136.) A straight conductor, carrying an alternating current, is arranged perpendicular to the lines of force of the field to be measured. The mechanical force acting on the conductor is applied to a piezoelectric crystal, and the a.c. output of the crystal is amplified.

621.317.73.011.21 **2556**

Admittance Meter for High Frequency.—J. Neumann. (*Funk u. Ton*, March 1952, Vol. 6, No. 3, pp. 113–122.) Description of a Rohde & Schwarz instrument for the range 0·1–10 Mc/s. A substitution method is used, resonance measurements being made on an LCR circuit with and without the element under test connected in parallel, readings being taken on the calibrated variable capacitor used for tuning. Eleven coils are provided for coverage of the total frequency range with adequate overlaps; a diode voltmeter is used as resonance indicator.

621.317.733.029.62 **2557**

A Bridged-T Impedance Bridge for the V.H.F. Band.—R. F. Proctor. (*Proc. Instn elect. Engrs*, Part III, March 1952, Vol. 99, No. 58, p. 105.) Summary only. Description of three bridges designed for the measurement, at 50–100 Mc/s, of complex impedances with resistances of 40–200 Ω and reactances between + 200 and − 200 Ω. Two of the bridges are suitable for measurement of the impedance between the two live terminals of a 3-terminal network; the third bridge is suitable for measurement of impedances balanced to earth.

621.317.755 : 621.314.7 **2558**

Apparatus for Testing Transistors.—P. J. W. Jochems & F. H. Stieltjes. (*Philips tech. Rev.*, March 1952, Vol. 13, No. 9, pp. 254–265.) Description of equipment for c.r.o. display of various transistor characteristics and for direct indication of transducer gain on a meter with decibel scale.

621.317.755 : 621.397.62 **2559**

Television Oscilloscope.—W. Tusting. (*Wireless World*, June & July 1952, Vol. 58, Nos. 6 & 7, pp. 233–236 & 280–283.) Television-receiver waveforms to be examined have repetition frequencies of 50 c/s–10·125 kc/s. Design requirements for oscilloscopes are considered in terms of 'sag' and rise time, which depend respectively on the low-frequency and high-frequency response of the circuits used; 5% and 1 μs are taken respectively as upper-limit values, using a 5-in. tube. A description, with complete circuit diagram, is given of equipment built to these requirements.

621.317.789 : 621.396.822 **2560**

The Design of an Equipment for Measuring Small Radio-Frequency Noise Powers.—K. E. Machin, M. Ryle & D. D. Vonberg. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 127–134.) The fundamentals of noise-power measurement are considered, the minimum detectable power being determined by the receiver noise and by the ratio of input and output bandwidths of the receiver. Inherent practical difficulties have been overcome by the design of self-balancing equipment in which a locally generated noise power is continuously adjusted to equality with the incoming power. The equipment is described, some sections in detail. The performance is analysed in terms of its accuracy, its response to an input step function and the fluctuations of its output indication; experimental performance figures compare reasonably well with theory.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534.232 : 621.315.612.4 : 620.178 **2561**

New Techniques for Measuring Forces and Wear in Telephone Switching Apparatus.—W. P. Mason & S. D.

White. (*Bell Syst. tech. J.*, May 1952, Vol. 31, No. 3, pp. 469–503.) Very rapid wear tests are made using the BaTiO$_3$ transducer described by Mason & Wick (1818 of 1951) to produce a normal or a tangential wearing force. The force is measured by inserting a BaTiO$_3$ ceramic plate at the point of application of the force and observing on a c.r.o. the piezoelectric voltage generated in the plate.

537.533 : 535.417 **2562**

Electron Interferometer.—L. Marton. (*Phys. Rev.*, 15th March 1952, Vol. 85, No. 6, pp. 1057–1058.) Discussion of the basic principles of an interferometer operating with electron beams.

621.3.012.8 : 629.11.012.8 **2563**

Application of the Methods of Electromagnetic Analogy to the Study of Motor-Car Suspension Systems.—G. Cahen. (*Onde élect.*, March 1952, Vol. 32, No. 300, pp. 89–90.) Comment on article noted in 1060 of April (Lansard).

621.365.55† **2564**

Temperature Distribution with Simultaneous Platten and Dielectric Heating.—H. M. Nelson. (*Brit. J. appl. Phys.*, March 1952, Vol. 3, No. 3, pp. 79–86.)

621.38.001.8 : 543/545 **2565**

Recent Developments in Electronic Instrumentation for Chemical Laboratories.—F. Gutmann. (*J. Brit. Instn Radio Engrs*, March 1952, Vol. 12, No. 3, pp. 161–180.) The account previously given (710 and 2308 of 1950) is brought up to date. 98 references.

621.384.611.1† **2566**

A Coil System for an Air-cored Betatron.—R. Latham, M. J. Pentz & M. Blackman. (*Proc. phys. Soc.*, 1st Feb. 1952, Vol. 65, No. 386B, pp. 89–93.) Description of the coil for a small betatron producing 300-keV electrons, and of measurements of the field configuration.

621.384.612.1† **2567**

A Fixed-Frequency Cyclotron with 225-cm Pole Diameter.—H. Atterling & G. Lindström. (*Nature, Lond.*, 15th March 1952, Vol. 169, No. 4298, pp. 432–434.) Designed to produce deuterons of energy 25 MeV, this unit is now in operation at the Nobel Institute for Physics, Stockholm. See also 2254 of 1951 (Atterling).

621.384.612.1† **2568**

The University of Birmingham Cyclotron.—(*Nature, Lond.*, 22nd March 1952, Vol. 169, No. 4299, pp. 476–477.) Deuterons of 20-MeV energy are obtained from this 10·24-Mc/s fixed-frequency unit.

621.385.833 **2569**

Magnetic Electron-Microscope Projector Lenses.—G. Liebmann. (*Proc. phys. Soc.*, 1st Feb. 1952, Vol. 65, No. 386B, pp. 94–108.) Theory previously given [1701 of June (Liebmann & Grad)] is applied to projector and similar lenses. The calculated results are in good agreement with measurements by Ruska.

621.385.833 **2570**

The Magnetic Electron Microscope Objective Lens of Lowest Chromatic Aberration.—G. Leibmann. (*Proc. phys. Soc.*, 1st March 1952, Vol. 65, No. 387B, pp. 188–192.)

621.387.424 **2571**

Toroidal Geiger Counters.—N. G. Trott. (*J. sci. Instrum.*, March 1952, Vol. 29, No. 3, pp. 87–88.) Two new types are described; in one, the cathode consists of a set of parallel wires, in the other of a wire helix.

PROPAGATION OF WAVES

538.566 **2572**

Universal Wave Polarization Chart for the Magneto-ionic Theory.—W. Snyder & R. A. Helliwell. (*J. geophys. Res.*, March 1952, Vol. 57, No. 1, pp. 73–84.) The expression for complex polarization given by the magneto-ionic theory is plotted on the complex plane, using normalized parameters related to ionization density and collision frequency. A further chart gives ellipticity and tilt angle related to the same normalized parameters. A chart is included for converting the normalized parameters to the corresponding values of ionization density and collision frequency. See also 1471 of 1951 (Scott).

621.396.11 **2573**

North Pacific Radio Warning Service.—(*Tech. Bull. nat. Bur. Stand.*, March 1952, Vol. 36, No. 3, pp. 33–34.) Twice-weekly forecasts of propagation conditions for local and long-distance communication circuits are issued by the N.B.S. centre at Anchorage, Alaska. 24-hour operation is envisaged.

621.396.11 **2574**

Comparison of Ionospheric Radio Transmission Forecasts with Practical Results.—A. F. Wilkins & C. M. Minnis. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 148–154.) Discussion on 2520 of 1951.

621.396.11 : 523.78 **2575**

Effect of the Annular Eclipse of March 7, 1951, on Radio-Wave Propagation.—(*Nature, Lond.*, 1st March 1952, Vol. 169, No. 4296, pp. 361–362.) Summary of paper by L. H. Martin, presented at the N.Z. Geophysical Conference. Observations made at Wellington on 11·75-Mc/s signals from GSD and 10-Mc/s signals from WWVH are reported; measurements were also made of received radio noise on frequencies ranging from 1·4 to 30 Mc/s. Effects due to the eclipse were difficult to segregate because it occurred soon after sunrise and because a magnetic storm of moderate intensity commenced on the same day. The results confirm those of previous observers in indicating that density of ionization and values of critical frequencies for the ionized layers decrease during the eclipse. The noise measurements are not conclusive; greater attention to this aspect should be given during future eclipses.

621.396.11 : 551.510.52 **2576**

Average Radio-Ray Refraction in the Lower Atmosphere.—M. Schulkin. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 554–561.) Corrections hitherto applied for atmospheric refraction in the calculation of radio field strengths are reviewed with particular regard to their application in ray-bending computations. A practical scheme is presented for calculating the atmospheric refraction of r.f. rays numerically from radiosonde data. Ray-bending computations are made for a range of climatological conditions for rays passing entirely through the atmosphere and departing or arriving tangentially at the earth's surface. About 90% of the ray bending occurs in the lowest 10 km of the atmosphere. Uncertainties in the determination of atmospheric refractive indices from meteorological sounding data are discussed.

621.396.11.029.51 **2577**

The Ionospheric Propagation of Radio Waves with Frequencies near 100 kc/s over Short Distances.—K. Weekes & R. Stuart. (*Proc. Instn elect. Engrs*, Part III, March 1952, Vol. 99, No. 58, pp. 99–102.) Summary only. Investigations of downcoming waves, isolated by the use of suitable aerial systems, are described. The transmitters used were those of the British chain of Decca navigation stations, which are all <150 km from the receiving sets in Cambridge. Diurnal and seasonal variations of the conversion coefficient (ratio of amplitude of abnormal component of downcoming wave to that of incident wave) are shown graphically. The average decrease in the apparent height of reflection around sunrise was 7–8 km, but the value was very variable from day to day. The effect of a sudden ionospheric disturbance is to decrease the amplitude of the downcoming wave very greatly and to decrease the apparent height of reflection by an amount which may be as large as 10 km and is the same on all frequencies from 16 to 113 kc/s.

621.396.11.029.51 **2578**

The Ionospheric Propagation of Radio Waves with Frequencies near 100 kc/s over Distances up to 1 000 km.—K. Weekes & R. Stuart. (*Proc. Inst elect. Engrs*, Part III, March 1952, Vol. 99, No. 58, pp. 102–105.) Summary only. An account of reception experiments at Swansea, Leeds and Cambridge at distances of about 300 and 900 km from Decca transmitting stations (British and Danish chains). The Hollingworth interference pattern was determined from signal-strength records obtained in an aircraft flying at a height of 2 000 ft. Typical results are shown graphically and discussed. Field-strength minima at 940 km from a 71-kc/s transmitter are noted and the changes of their times of occurrence throughout a year are shown. Records indicate that during a sudden ionospheric disturbance the amplitude of the downcoming wave is greatly increased. In a large disturbance it was deduced that the reflection coefficient (ratio of amplitude of normal component of downcoming wave to that of incident wave) for 71-kc/s wave was increased by a factor of nearly 6. On the higher frequencies the increase appeared to be rather smaller.

621.396.11.029.55 **2579**

Instantaneous Prediction of Radio Transmission Paths.—O. G. Villard, Jr, & A. M. Peterson. (*QST*, March 1952, Vol. 36, No. 3, pp. 11–20.) Report of an investigation of the occurrence of back scatter as a transmission path becomes serviceable. 'Scatter-sounding' records made at 5-min intervals during a 24-hour period are compared with the strength of signals received from some 300 amateur R/T stations during this time in the 14-Mc/s band. Maps show the correlation between scatter areas around the central transmitter and the location of stations heard. The corresponding c.r.o. scatter patterns are shown. The results obtained indicate that scatter soundings, which can be made with ordinary amateur transmitting and receiving equipment, show the areas to which radio transmission is possible, via both the F and sporadic-E layers. As a prediction method for communication, scatter sounding is remarkably sensitive and comparatively simple.

621.396.11.029.62 **2580**

Abnormal Ranges of Ultrashort Waves and their Meteorological Causes.—B. Abild. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, Jan./Feb. 1952, Vol. 4, Nos. 1/2, pp. 4–11.) Theory of the effects of variations of temperature and relative humidity, and of inversions of the refractive-index gradient, is briefly reviewed, and a detailed account is given of investigations of the relation between the signal strength at Flensburg of 89·3-Mc/s transmissions from Hamburg and the meteorological conditions over the 150-km transmission path. In general, a close correlation exists between the signal strength and the difference between the relative humidities at ground level and at 900-mb level. The highest values of signal strength occur when there is a pronounced inversion near the ground. Sudden changes of moisture content at heights of 200–800 m have little effect in producing abnormal ranges, but inversions at heights of about 1 km have a large effect. Low values of signal strength are observed when the lower 2 km of the atmosphere have no pronounced layered structure. Typical records show the general correspondence between the strength of the received signal and the gradient of the refractive index at moisture-content discontinuities at heights up to 1·5 km. Other records illustrate the effect of squally conditions, the occurrence of thunderstorms, and the passage of warm fronts.

621.396.11.029.62 : 551.510.535 **2581**

A New Kind of Radio Propagation at Very High Frequencies observable over Long Distances.—D. K. Bailey, R. Bateman, L. V. Berkner, H. G. Booker, G. F. Montgomery, E. M. Purcell, W. W. Salisbury & J. B. Wiesner. (*Phys. Rev.*, 15th April 1952, Vol. 86, No. 2, pp. 141–145.) The discovery and some results of a preliminary investigation of weak v.h.f. propagation via the ionosphere are reported. Some preliminary speculations suggest that the mechanism concerned in such propagation may be scattering caused by ever-present irregularities in the E region. An approximate transmission equation is derived in terms of parameters describing inhomogeneities in this region. Experiments carried out on a frequency of 49·8 Mc/s over a test path of 1 245 km always showed an observable signal irrespective of season, time of day, or geomagnetic disturbance, although showing dependence of signal strength on these factors and possibly on meteor activity as well. During sudden ionospheric disturbances when h.f fade-outs occurred, the signal showed no evidence of weakening and was usually enhanced. For shorter accounts see *Electronics*, June 1952, Vol. 25, No. 6, pp. 102–103, and *Wireless World*, July 1952, Vol. 58, No. 7, pp. 273–274.

621.396.8.029.51 **2582**

Phase Variations with Range of the Ground-Wave Signal from C.W. Transmitters in the 70-130 kc/s Band.—A. B. Schneider. (*J. Brit. Instn Radio Engrs*, March 1952, Vol. 12, No. 3, pp. 181–194.) Phase-variation/distance curves are plotted for a uniform smooth earth for various values of conductivity, using Norton's (1596 of 1942) and Bremmer's (3242 of 1949) formulae. Confirmation of the curves is provided by phase measurements within the reactive field of a c.w. radiator and along the base-line extensions of a Decca navigator chain. For the case of an inhomogeneous earth, a simple method of assessing the variation of phase with distance is suggested and is illustrated by an analysis of readings on the Decca navigator system.

621.396.8.029.51 **2583**

Random Phase Variations of C.W. Signals in the 70-130 kc/s Band.—W. T. Sanderson. (*J. Brit. Instn Radio Engrs*, March 1952, Vol. 12, No. 3, pp. 195–205.) "The accuracy of c.w. navigational aids in this frequency band depends fundamentally on the phase stability of the received signals, which in turn is determined by skywave effects. The r.m.s. phase errors depend on the relative amplitude of skywave and groundwave, and a method is given for assessing the phase errors in Northern Europe at any given time and range from the transmitter. For the sake of simplicity a number of approximations are made and the resulting limitations are discussed. The predicted and observed errors on the Decca Navigator Chains in England and Denmark are compared, and it is concluded that the method gives sufficiently accurate results for most practical purposes. Some comments are added on the variations of errors with height."

621.396.81.029.62 **2584**

U.S.W. Field Strength Predictions for Mountainous Terrain.—E. Bauermeister & W. Knöpfel. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, March/April 1952, Vol. 4, Nos. 3/4, pp. 67–73.) Field-strength investigations in the Feldberg district of the Black Forest formed the basis of a method for predicting field strengths in the 3-m wavelength region, particularly for places at which multiple refraction and reflection effects are important. The field strength is determined from (*a*) the free-space field strength and (*b*) attenuation factors which take account of the different refractions and reflections that occur. Further measurements in the Moselle valley district confirmed the usefulness of the method.

621.396.81 + 621.396.677.012.71 **2585**

Aerial Measurements in the Microwave Range.—Seppen. (See 2446.)

621.396.812.029.64 **2586**

Volume Integration of Scattered Radio Waves.—A. H. LaGrone. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, p. 551.) Corrections to paper noted in 1412 of May.

621.396.812.3 : 519.272 : 681.142 **2587**

A Computer for Correlation Functions.—Brooks & Smith. (See 2547.)

RECEPTION

621.396.621 **2588**

Linear Rectifiers and Limiters.—D. G. Tucker. (*Wireless Engr*, May 1952, Vol. 29, No. 344, pp. 128–137.) Theoretical analysis for an applied signal consisting of a carrier (envelope-modulated or unmodulated) accompanied by other tones or noise. The analysis, which is strictly applicable only when the carrier is the predominant input component, is based on a representation of the rectifier or limiter by a switching function whose form is determined by the applied signal and which is expressed in terms of a series of Bessel functions. Consideration is given to the effect on the signal/noise ratio when the detector is used as a frequency multiplier.

621.396.621 : 621.396.619.13 **2589**

F.M. Receiver Modification.—J. G. Spencer. (*Wireless World*, May 1952, Vol. 58, No. 5, p. 204.) A note of minor modifications to the receiver previously described (1093 of April) necessary to replace the Type-X81 frequency changer, now obsolescent, by a Type-X79 valve. Performance is practically unaffected.

621.396.622 : 621.396.619.13 **2590**

Detection of F.M. Waves.—Basseras. (*Radio franç.*, March 1952, No. 3, pp. 21–24.) General description of the method using a limiter and discriminator, with particular reference to the use of an oscillating circuit as discriminator and to the action of the Travis and Foster-Seeley discriminators.

621.396.621.029.6 **2591**

Empfangsprobleme im Ultrahochfrequenzgebiet, unter besonderer Berücksichtigung des Halbleiters (U.H.F. Reception Problems, with particular reference to Semiconductors). [Book Review]—H. F. Mataré. Publishers: R. Oldenbourg, Munich, 1951, 264 pp., 37.80 fr. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st March 1952, Vol. 30, No. 3, pp. 119–120.) A comprehensive treatment, dealing particularly with methods of frequency mixing, amplification, detection, sensitivity and noise, design calculations, and test equipment and methods.

STATIONS AND COMMUNICATION SYSTEMS

621.3.015.7(083.7) **2592**

Standards on Pulses: Definitions of Terms: Part 2, 1952.—(*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 552–554.) Standard 52 IRE 20S1. Part 1: see 2826 of 1951.

621.39 **2593**

Modern Systems of Long-Distance Communication.—R. Sueur. (*Bull. Soc. franç. Élect.*, March 1952, Vol. 2, No. 15, pp. 123–139.) A short review of systems used up to 1940, with a general description of the principles of modern systems using carrier currents, underground balanced-pair or coaxial cables, submarine cables, or radio beam systems for the transmission of telephony, telegraphy, broadcasting or television signals. The economics of the various systems is discussed and basic considerations which should determine future developments are outlined.

621.39.001.11 **2594**

A Comparison of Signalling Alphabets.—E. N. Gilbert. (*Bell Syst. tech. J.*, May 1952, Vol. 31, No. 3, pp. 504–522.) Two channels are considered, (*a*) a discrete channel transmitting sequences of binary digits, and (*b*) a continuous low-pass channel. The rate of signalling is computed for a large number of simple alphabets; rates near the channel capacity cannot be attained without using very complicated alphabets.

621.39.001.11 **2595**

A Link between Information and Energy.—J. H. Felker. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 728–729.) Discussion of the ultimate limits of low-power operation of switching systems, computers, and other communication machinery. Calculation indicates that for the passage of 10^6 'bits' of information per second the power required is $> 2{\cdot}85 \times 10^{-15}$ W.

621.395.44 **2596**

Transmission Characteristics of the V60 Carrier-Frequency Equipment.—F. Ring. (*Fernmeldetech. Z.*, March & April 1952, Vol. 5, Nos. 3 & 4, pp. 101–108 & 179–186.) C.C.I.F. requirements for a 60-channel system are outlined and the specification for the V60 equipment is described. Tests carried out on the Frankfurt-Mannheim cable, with repeaters at Erzhausen, Hahn and Lorsch, gave results in good agreement with theory.

621.395.65 : 621.318.572 **2597**

An Experimental Electronically Controlled Automatic Switching System.—W. A. Malthaner & H. E. Vaughan. (*Bell Syst. tech. J.*, May 1952, Vol. 31, No. 3, pp. 443–468.) An experimental telephone switching system is described; its use enables the number of control and connector circuits to be reduced.

621.395.97 : 621.395.645 **2598**

Radio-Diffusion Amplifiers for Standard [telephone] **Circuits.**—Jacot. (See 2468.)

621.396 : 061.3 **2599**

Extraordinary Radio-Communication Administrative Conference, Geneva, 1951 (C.A.E.R.).—H. Pressler, (*Fernmeldetech. Z.*, March 1952, Vol. 5, No. 3, pp. 132–136.) Report of the proceedings.

621.396.018.78 : 621.396.677 **2600**

Signal Distortion by Directional Broadcast Antennas.—C. H. Moulton. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 595–600.) Measurements on transmissions from two broadcasting stations with directive aerial systems show that signal distortion occurs and is a function of the direction of reception. Distortion results from changes produced by the directive aerial system in the magnitudes or relative phases of the signal components; it is accentuated by the existence of deep nulls in the radiation pattern, by small aerial bandwidth, by high audio modulation frequency, and by high degree of modulation.

621.396.619.13 : 621.396.66 **2601**

An Aural Monitor for Frequency Modulation.—J. L. Hathaway & R. E. Lafferty. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 545–547.) The aural monitor at a f.m. station should be responsive to a.m. to a degree at least equivalent to that of ordinary receivers with little or no limiting. This requirement, as well as others, can be met by proper application and adjustment of a 'slope detector.' Two units, which are compact and have been found reliable, are described. The simpler unit is suitable for TV sound on one of the lower v.h.f. channels; the other, a heterodyne type, can be used for any TV channel.

621.396.619.13.018.78 : 621.392.43 **2602**

Effect of Aerial-Feeder Mismatch on the Distortion in Frequency-Modulation Transmission.—E. Kettel. (*Telefunken Ztg*, March 1952, Vol. 25, No. 94, pp. 41–50.) Analysis shows that mismatch causes both amplitude and phase distortion owing to reflection effects. For matching conditions attainable in practice it is sufficient to consider only the strongest of such reflections. In the case of receivers using amplitude limiting, only distortion of the instantaneous frequency results from mismatch; this gives a distortion coefficient which increases with the modulation frequency but with normal matching and feeder lengths remains within tolerable limits for broadcast transmissions. For simpler receivers without limiters, using signal-flank demodulation, considerably greater distortion is produced by the a.m. due to mismatch.

In the case of a carrier-frequency multichannel telephony system, the phase distortion due to aerial mismatch produces nonlinear crosstalk between the individual channels; calculations indicate that in many cases this can only be reduced to a negligible amount by limitation of the feeder length.

621.396.619.16 **2603**

Delta Modulation, a New Modulation System for Telecommunication.—J. F. Schouten, F. de Jager & J. A. Greefkes. (*Philips tech. Rev.*, March 1952, Vol. 13, No. 9, pp. 237–245.) A form of pulse modulation is described in which the signals transmitted are quantized both in time and in amplitude, so that cumulative interference picked up in the transmission channel may be eliminated at the receiver. The transmitter uses a form of inverse feedback, such that any signal transmitted is only a correction of the preceding one; the system thus approximates to the optimum in which no superfluous information is transmitted. Freedom from interference is secured at the expense of bandwidth, but the system described utilizes bandwidth more efficiently than any other in existence except p.c.m. systems, which need very much more complicated apparatus. See also 2330 of August (Libois).

621.396.619.16 : 621.394/.396 **2604**

Use of Pulse Technique in the Establishment of Complex Transmission Networks.—G. Potier. (*Onde élect.*, April/May 1952, Vol. 32, Nos. 301/302, pp. 197–201.) Discussion of multiplex time-sharing transmission methods. Such systems are technically and economically advantageous and their flexibility renders their application practicable for both simple and complex transmission networks.

621.396.619.16 : 621.396.4 **2605**

Use of Pulse Modulation for Transmission in a Group of Telephony Channels of a Carrier-Current System.—L. J. Libois. (*Onde élect.*, April/May 1952, Vol. 32, Nos. 301/302, pp. 190–196.) Distortion in pulse modulation due to the sidebands of the modulation spectrum and to the limitation of the transmission channel bandwidth is discussed, and also the nonlinearity of the modulation characteristic. Comparison of pulse-modulation multiplex with time sharing and with frequency sharing is made with regard to the signal/noise ratio for the two methods, which from this point of view are found to be practically equivalent. See also 2331 of August.

621.396.619.16 : 621.396.41 : 621.396.822.1 **2606**

Crosstalk in Time-Division-Multiplex Communication Systems using Pulse-Position and Pulse-Length Modulation.—J. E. Flood. (*Proc. Instn elect. Engrs*, Part III, March 1952, Vol. 99, No. 58, pp. 106–108.) Summary only. Some of the results previously obtained for p.a.m. systems [2830 of 1951 (Flood & Tillman)] are extended to pulse-position and pulse-length modulation systems. Sets of curves show the crosstalk as dependent on the number of stages of the resistance-coupled amplifier used and on the time constant common to all stages.

621.396.65 **2607**

Some Data on Two Former Multichannel Beam Links from Athens to Rome and Crete.—K. O. Schmidt. (*Telefunken Ztg.*, March 1952, Vol. 25, No. 94, pp. 64–68.) A few details are given of aerials, relay stations and equipment, installed in 1941, operating on wavelengths in the range 70–80 cm and providing three telephony and twelve voice-frequency telegraphy channels.

621.396.65 : 621.396.41 : 621.396.822 **2608**

Evaluation of the Signal/Noise Ratio for a Multiplex Radio Link.—J. Dascotte. (*Onde élect.*, April/May 1952, Vol. 32, Nos. 301/302, pp. 202–208.) A formula is given for the signal/noise ratio which involves the peak power of the carrier wave, the gain of the transmitting and of the receiving aerial relative to a $\lambda/2$ dipole, the losses in the two feeders, the theoretical free-space attenuation between two $\lambda/2$ dipoles for the transmission path and frequency, the noise factor of the receiver, and losses due to the terrain and the heterogeneity of the atmosphere. Use is made of abacs given by Bullington (802 of 1948 and 436 of 1951). Estimates are made of losses due to the terrain for paths within and beyond the optical range.

621.396.65 : [621.396.43 + 621.397.26 **2609**

The Equipment of the Paris-Lille Radio Link.—H. Gutton, J. Fagot & J. Hugon. (*Onde élect.*, April/May 1952, Vol. 32, Nos. 301/302, pp. 174–180.) Discussion of technical considerations which determined the broad lines of development of the C.G.T.S.F. system, operating on 8-cm wavelength, and description of aerial switching arrangements, relays, aerials, filters, and u.h.f. amplifiers using travelling-wave valves. See also 2028 of July (Marzin).

621.396.65 : 621.396.5 **2610**

The Contribution of Radio Beam Links in the Field of Telecommunications.—R. Cabessa. (*Onde élect.*, April/May 1952, Vol. 32, Nos. 301/302, pp. 131–151.) Radio and line systems are compared from the point of view of transmission quality, noise characteristics, secrecy and cost. Quality requirements for complete circuits, as specified by the C.C.I.F., are correlated with the characteristics of the radio equipment and propagation medium as defined by the C.C.I.R. Short descriptions are given of existing installations in Europe and in the U.S.A.

621.396.65 : 621.396.5 **2611**

Radio Beam Links in Modern Telephone Networks.—R. Sueur & L. J. Libois. (*Onde élect.*, April/May 1952, Vol. 32, Nos. 301/302, pp. 121–130.) General discussion of the characteristics of beam links and their application for short-distance and long-distance telephone communication and for extension of line systems. A few details are given of the equipment for beam links recently brought into service in France; short-distance links use multiplex pulse modulation, while f.m. is used for long-distance operation.

621.396.65 : 621.396.5 **2612**

Inauguration of the Dijon-Strasbourg Radio Beam Telephony Link.—M. Lorach. (*Électronique, Paris,* March 1952, No. 64, pp. 6–8, 45.) A short illustrated description of the equipment, which comprises two underground cables linking Dijon with the radio transmitter on Mont Affrique, 7 km away, and beam links thence to Strasbourg, with relay stations on Montfaucon, near Besançon, and on the Ballon de Guebwiller. Wavelengths on the three sections for transmissions from Dijon are respectively 1·25, 1·09 and 1·25 m; in the opposite direction the wavelengths are 1·13, 1·20 and 1·13 m, the changes at the relay stations being made to isolate the incoming from the outgoing signals.

621.396.65 : 621.396.5 **2613**

The Equipment of the Dijon-Strasbourg Radio Beam Link.—P. Rivère & M. Schwindenhammer. (*Onde élect.,* April/May 1952, Vol. 32, Nos. 301/302, pp. 163–173.) Detailed illustrated description of terminal and relay-station equipment, with simplified circuit diagrams. See also 2612 above.

621.396.65.029.62 **2614**

A 50-Mc/s Beam Link with ± 500-kc/s Frequency Swing.—H. J. Fründt. (*Telefunken Ztg,* March 1952, Vol. 25, No. 94, pp. 51–59.) General description of equipment, including a quartz-controlled 1-kW transmitter and selective receiver, providing multichannel communication between Western Berlin and Torfhaus, in the Harz mountains. Results are given of measurements of transmitter and receiver distortion, and noise factor.

621.396.712(43-16) **2615**

The Technical Installations of the N.W.D.R., 1st January 1952.—(*Tech. Hausmitt. NordwDtsch. Rdfunks,* Jan./Feb. 1952, Vol. 4, Nos. 1/2, pp. 21–25.) A list of the medium-wave and f.m. u.s.w. stations, giving height above sea level, frequency, power, type of transmitter and type of aerial, a few details of the experimental television transmitter and of the monitoring stations at Wittsmoor, Hamburg and Norderney, and particulars of the various broadcasting studios, including size of rooms and their mean reverberation times.

621.396.933 **2616**

Service Range for Air-to-Ground and Air-to-Air Communications at Frequencies above 50 Mc/s.—R. S. Kirby, J. W. Herbstreit & K. A Norton. (*Proc. Inst. Radio Engrs,* May 1952, Vol. 40, No. 5, pp. 525–536.) Propagation aspects of communication with aircraft are discussed and contours of equal received signal strength are shown in the form of lobes for various frequencies. For systems with equivalent transmitted power, ground-aerial height, and transmitting- and receiving-aerial gain, the service range decreases with increase of frequency. This is due primarily to decrease of the absorbing area of the receiving aerial and to a larger number of nulls in the lobe structure owing to interference between direct and ground-reflected waves. Ground-station aerial-height diversity and tilted-array ground-aerial systems are discussed as a means of obtaining improved coverage at the higher frequencies.

621.396.97 + 621.396.932/.933].1 **2617**

Common-Wave Broadcasting and Hyperbolic Navigation.—Pohontsch. (See 2515.)

621.396.97 : 621.316.729 **2618**

The Radio Common-Wave System of the S.W.F. [Südwestfunk].—A. Kolarz, E. Kniel & K. H. Baer. (*Tech. Hausmitt. NordwDtsch. Rdfunks,* March/April 1952, Vol. 4, Nos. 3/4, pp. 47–51.) In order to improve the frequency stability of the Bad Dürrheim, Ravensburg and Reutlingen transmitters, a radio method of synchronization was developed, utilizing the 200-kc/s transmissions from Droitwich as a frequency standard. After demodulation and amplification the signals are used to lock the frequency of a 100-kc/s quartz oscillator from which is derived, by a process of frequency multiplication, division and mixing, a frequency of 1 538 kc/s which locks the frequency of a quartz oscillator used to control the broadcasting transmissions. An independent 1 538-kc/s quartz oscillator is available for use when the Droitwich transmitter is not operating, or when fading or other causes render the synchronization unreliable.

SUBSIDIARY APPARATUS

621-526 **2619**

Stability of Control Systems. Methods of Study.—J. Kuntzmann, J. Daniel & Min-Yuan Ma. (*Rev. gén. Élect.,* March 1952, Vol. 61, No. 3, pp. 149–152.) Two methods of examining the stability of a system are discussed, the method of response curves and one depending on zone separation in the complex plane. The first method is convenient when the effect of only one parameter is to be determined; the second is preferable when two or more parameters are concerned.

621-526 **2620**

Amplifying Dynamos. Their Use in Servomechanisms.—G. Lehmann. (*Onde élect.,* March 1952, Vol. 32, No. 300, pp. 78–88.)

621.314.632.1 + 621.314.634].011.22 **2621**

Measurement of the D.C. Resistance of Selenium and Copper Oxide Rectifiers below Room Temperature.—D. M. Grimes & S. Legvold. (*J. appl. Phys.,* March 1952, Vol. 23, No. 3, pp. 312–315.) Results for temperatures (T) from 79° to 300°K show that the logarithm of the resistance is nearly a linear function of 1/T in all cases except for the reverse direction in Se rectifiers, for which the resistance (with 6 V applied) has a minimum value below 200°K.

621.314.634 **2622**

Some Further Observations on the Effect of Bending on Selenium Rectifier Discs.—P. Selényi. (*Proc. phys. Soc.,* 1st Feb. 1952, Vol. 65, No. 386B, pp. 161–162.) See also 86 of 1948.

621.316.721 **2623**

General Theory of Current Stabilizers.—J. J. Gilvarry & D. F. Rutland. (*Rev. sci. Instrum.,* March 1952, Vol. 23, No. 3, pp. 111–114.) The theory of voltage stabilizers previously developed (814 of March) is extended to deal with current stabilizers; the performance of an arbitrary stabilizer is completely specified by four parameters. The effect on stabilizer current of load-resistance variation is evaluated. Two special cases are discussed.

621.351/.355 **2624**

Modern Batteries and Accumulators used in Telecommunications.—J. Pernik. (*Ann. Télécommun.,* March 1952, Vol. 7, No. 3, pp. 145–148.) Complementary to paper noted in 3120 of 1951. Construction and discharge characteristics of different cells are discussed, including primary cells with air depolarization and Ni-Fe and Ni-Cd alkaline accumulators.

TELEVISION AND PHOTOTELEGRAPHY

621.397.242 : 621.395.51 **2625**

The London-Birmingham Television-Cable System.—T. Kilvington, F. J. M. Laver & H. Stanesby. (*Proc. Instn elect. Engrs*, Part I, March 1952, Vol. 99, No. 116, pp. 44–58. Discussion, pp. 59–62.) The cable itself has been described by Stanesby & Weston (1279 and 1857 of 1949). An account is here given of the general arrangements providing channels for relaying television signals simultaneously in both directions between central points in the two cities, with extensions to the transmitters at Alexandra Palace and Sutton Coldfield. Details are given of the line amplifiers, which have uniform gain over the working-frequency range 3–7 Mc/s, the cable loss being equalized over the same range. Supervisory and power equipment, and terminal modulation and demodulation equipment, are described, with typical test results showing modulator and demodulator performance on 10-μs pulses and sawtooth signals, overall vision-frequency characteristics, and test patterns before and after transmission from Alexandra Palace to Birmingham and back.

621.397.26 + 621.396.43] : 621.396.65 **2626**

The Equipment of the Paris-Lille Radio Link.—Gutton, Fagot & Hugon. (See 2609.)

621.397.26 : 621.396.65 **2627**

The Paris-Lille Television Radio Link.—Y. Angel & P. Riche. (*Onde élect.*, April/May 1952, Vol. 32, Nos. 301/302, pp. 152–157.) Historical account of developments leading to the establishment of the link and general description of its technical features, with ground-contour diagrams for the three sections of the 218-km path. See also 819 of March.

621.397.26 : 621.396.65 **2628**

The Equipment of the Paris-Lille Television Radio Link.—J. Laplume, S. Schirman, R. Fraticelli & R. Jeannin. (*Onde élect.*, April/May 1952, Vol. 32, Nos. 301/302, pp. 158–162.) Detailed description of terminal and relay-station equipment developed by the C.F.T.H. and operating on frequencies of 940 and 905 Mc/s. See also 819 of March.

621.397.5 **2629**

The British Contribution to Television.—(*Engineering, Lond.*, 2nd & 9th May 1952, Vol. 173, Nos. 4501 & 4502, pp. 553 & 603; *Engineer, Lond.*, 2nd May 1952, Vol. 193, No. 5023, pp. 607–608.) Report of convention arranged by the Institution of Electrical Engineers in April/May 1952, with summaries of some of the papers presented. These are to be published in full in four special issues of *Proc. Instn elect. Engrs*, Part IIIA. See also *Wireless World*, June 1952, Vol. 58, No. 6, p. 212, and *Nature, Lond.*, 26th July 1952, Vol. 170, No. 4317, pp. 136–138.

621.397.5 **2630**

Television-Image Reproduction by use of Velocity-Modulation Principles.—M. A. Honnell & M. D. Prince. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, p. 604.) Reply of one of the authors to comment by Thomas (823 of March).

621.397.5(083.74) : 621.397.335 **2631**

Variant of the Frame Synchronizing Sequence of the C.C.I.R. 625-Line Standard.—H. Laett. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, 1st March 1952, Vol. 30, No. 3, pp. 87–90. In French and German.) At the plenary session of the C.C.I.R., June 1951, the synchronization signal adopted consisted of three groups of six pulses each. A proposal by the Swiss delegation for the groups to have five pulses was not discussed, owing to lack of time, but has now been approved by correspondence and will be included in the final report of the proceedings. Discussion indicates that while the six-pulse group is very suitable for the American 525-line 60-fields/sec system, it is not suitable for a 625-line 50-fields/sec system if the synchronization signal is to be derived directly from the mother frequency. The five-pulse signal is shown graphically. The two variants are practically equivalent as regards receiver operation.

621.397.611.2 **2632**

Improvements in Design and Operation of Image-Iconoscope Type Camera Tubes.—J. E. Cope, L. W. Germany & R. Theile. (*J. Brit. Instn Radio Engrs*, March 1952, Vol. 12, No. 3, pp. 139–149.) Television camera tubes using high-velocity electrons for scanning are liable to spurious signals and edge flare due to non-uniform redistribution of secondary electrons over the storage surface. A description is given of an improved photicon image iconoscope in which these undesirable effects are reduced by flooding the storage surface with low-velocity electrons from an adjacent annular photo-emission surface. A simplified camera control unit can be used since the 'black' picture signal is constant in relation to the level during beam suppression; a simple clamp circuit provides a satisfactory average-brightness component.

621.397.62 **2633**

Television Developments — a Selection from the I.E.E. Convention of Points Applicable to Receivers.—(*Wireless World*, June 1952, Vol. 58, No. 6, pp. 210–211.)

621.397.62 **2634**

Line Eliminator. 'Spot Stretching' as an Alternative to Spot Wobbling.—G. N. Patchett. (*Wireless World*, June 1952, Vol. 58, No. 6, pp. 219–221.) Line visibility in a television receiver is reduced, without impairing horizontal definition, by using an elongated spot, the longer axis being vertical. The required auxiliary focusing device is most conveniently placed between the main focusing device and the deflector coils. Photographs of B.B.C. Test Card C illustrate improvements obtained.

621.397.62 **2635**

A New U.H.F. Television Converter.—H. Hesse. (*Tele-Tech*, March 1952, Vol. 11, No. 3, pp. 36–39 . . 118.) Description of a self-contained u.h.f.-v.h.f. conversion unit continuously tunable over the 470–890-Mc/s band.

621.397.62 : 621.317.755 **2636**

Television Oscilloscope.—Tusting. (See 2559.)

621.397.621 **2637**

Workshop Construction of a Scanning Assembly for a Wide-Angle Flat-Faced Tube.—M. Duchaussoy & M. Guillaume. (*Télévision*, March/April & May 1952, Nos. 22 & 23, pp. 75–79 & 104–108.) Detailed instructions for shaping the yoke, winding the deflection coils and mounting the whole assembly complete with focusing coil and deflection circuits.

621.397.621 : 621.385 **2638**

Line-Scanning Valves and Circuits.—B. Eastwood & C. C. Vodden. (*J. Brit. Instn Radio Engrs*, March 1952, Vol. 12, No. 3, pp. 150–160.) In high-efficiency line-scanning circuits the valves have to withstand peak voltages amounting to some thousands of volts during the cut-off part of the cycle; the special design problems of mass-production valves for use in these circuits are discussed. In pentodes and tetrodes thermionic emission from the screen grid is reduced by suitable processing and by aligning with the control grid. Insulation requirements are examined.

621.397.645 **2639**

A Study of Grounded-Grid, Ultra-High-Frequency Amplifiers.—T. Murakami. (*RCA Rev.*, Dec. 1951, Vol. 12, No. 4, pp. 682–701.) Though the high cost of u.h.f. amplifiers may prevent their general adoption in domestic television receivers, they are needed for particular applications. The performances of amplifiers using several different types of valve are compared; theoretical curves are given for amplifier gain and for the noise factor of amplifiers with matched or mismatched input or output circuits. Experimentally determined noise factors for amplifiers using types 5876 and 416A triodes are in good agreement with computed values. The use of a grounded-grid amplifier reduces the amount of local-oscillator signal passed back to the aerial; experimental curves are given showing the attenuation from output to input of an amplifier using (*a*) a type-5876 triode, and (*b*) a type-416A triode.

621.397.7 **2640**

Kirk o'Shotts Television Transmitting Station.—(*Engineer, Lond.*, 14th March 1952, Vol. 193, No. 5016, pp. 371–373). Further details, including descriptions of the medium-power equipment, the coaxial-cable links between Alexandra Palace, Birmingham and Manchester, and the microwave radio link between Manchester and Edinburgh. See also 3143 of 1951.

621.397.82 **2641**

Interference in Television Pictures. Effect of Line-Deflection Circuits.—G. Diemer, Z. van Gelder & J. J. P. Valeton. (*Wireless Engr*, June 1952, Vol. 29, No. 345, pp. 164–168.) Barkhausen oscillations are discounted as a cause of h.f. interference effects giving rise to vertical lines on the left-hand side of a television screen. These are ascribed to irregularities above the knee of the I_a/V_a characteristic of the power valve used in the line-deflection circuit. The most important factor influencing the intensity of the interference is the leakage inductance of the transformer.

621.397.82 **2642**

Relative Magnitudes of Undesired Responses in Ultra-High-Frequency Receivers.—Wen Yuan Pan. (*RCA Rev.*, Dec. 1951, Vol. 12, No. 4, pp. 660–681.) The relative strengths of interfering signals in u.h.f. television receivers using crystal mixers are measured with equipment basically similar to commercially available tuners and converters (see 442 of 1951), except that no selective circuit is connected in front of the mixer. Cases are grouped into single-frequency and two-frequency interference, either dependent on or independent of local-oscillator frequency. The test results are applied in designing the pre-mixer circuits to give required selectivity.

621.397.5 **2643**

Fernsehen (Television). [Book Review]—F. Kerkhof & W. Werner. Publishers: Philips, Eindhoven, 1951, 506 pp. 28 DM. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, Jan./Feb. 1952, Vol. 4, Nos. 1/2, p. 27.) An introduction to the physical and technical principles of television technique. Advanced mathematical treatments are avoided as far as possible.

TRANSMISSION

621.396.61 : 621.396.712 **2644**

The Ravensburg 2 × 20-kW Broadcasting Transmitter.—A. Kolarz, A. Schweisthal & K. H. Baer. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, March/April 1952, Vol. 4, Nos. 3/4, pp. 34–42.) Special precautions were taken in the development of a 20-kW transmitter using Doherty modulation, to obtain high quality without sacrificing simplicity of construction. The performance obtained was found superior to that of an anode-modulation transmitter of the newest type, the superiority being more evident the higher the quality demanded in the reproduction.

621.396.61 : 621.396.712 **2645**

Twin Drive as Active Reserve for Broadcasting Transmitters.—A. Schweisthal. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, March/April 1952, Vol. 4, Nos. 3/4, pp. 42–45.) Discussion of the advantages of an arrangement in which two identical transmitters are connected via a bridge network to a single aerial. In case of failure of either transmitter, the other continues to transmit alone until the fault has been corrected. The arrangement is considered more economical than that in which a stand-by transmitter is provided and seldom used.

621.396.61.029.62 : 621.396.712 **2646**

An U.S.W. Frequency Converter.—A. Kolarz & B. Pick. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, March/April, 1952 Vol. 4, Nos. 3/4, pp. 62–66.) Description of relay-station equipment for the frequency range 87–100 Mc/s. A single quartz oscillator is used in conjunction with a local oscillator and three mixer stages. The temperature coefficient of the quartz crystal is so low that a thermostat is unnecessary; its frequency is equal to the frequency difference required between input and output, and the mixing arrangements are such that frequency changes of the local oscillator affect only the i.f. and have no effect on the output frequency.

621.396.615.14 : 621.396.619.13 **2647**

New Master Oscillator of High Frequency Stability for F.M. U.S.W. Broadcasting Transmitters.—E. Kettel. (*Telefunken Ztg*, March 1952, Vol. 25, No. 94, pp. 60–64.) General description, with outline circuit diagram, of equipment for the 87·7–100 Mc/s range, comprising oscillator and modulator with quartz-crystal control unit giving frequency constancy to within 2 parts in 10^6.

621.396.712 : 621.396.61 : 621.398 **2648**

Problems of Automatic Operation of Transmitter Groups.—A. Kolarz & E. Kneil. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, March/April 1952, Vol. 4, Nos. 3/4, pp. 59–62.) The S.W.F. (Südwestfunk) caters for three districts with different types of population and culture. Problems of programme switching for the various m.f., h.f. and u.h.f. transmitter groups are discussed and present facilities are described. Monitoring of the transmission quality of all transmitters is carried out by means of a suitably equipped motor van, normally stationed in Baden-Baden.

VALVES AND THERMIONICS

537.533/.534 : 621.385.2 **2649**

Ions and Electrons with Uniform Initial Velocities in a Vacuum.—F. Wenzl. (*Z. angew. Phys.*, March 1952, Vol. 4, No. 3, pp. 94–104.) Theoretical analysis for a planar diode system. A solution of the space-charge equation is obtained in terms of elliptic integrals. For the case of a periodic potential distribution, the relation between period and amplitude is investigated; the potential distribution can be represented with fair accuracy by trigonometrical approximations if the amplitudes are not too large. The occurrence of a virtual cathode is investigated for the case of anode emission of ions with zero initial velocity; close qualitative analogies are found with the case of pure electron flow. Questions of stability and the realizability of a periodic potential distribution are discussed.

537.582.004.15 **2650**

The Efficiency of Thermal Electron Emission.—M. J. O. Strutt. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 601–603; *Bull. schweiz. elektrotech. Ver.*, 3rd May 1952, Vol. 43, No. 9, pp. 350–353, in German.) The efficiency is defined as the ratio of the total kinetic energy of the emitted electrons to the heater power applied to a cathode. Assuming losses are solely due to heat radiation, an expression for the optimum efficiency is derived. This efficiency can never be reached with ordinary cathodes. The efficiency determined from experimental results for a tungsten cathode was 0·18%, and for an oxide layer on a Pt-Ir base 3·5%. Comparison with the theory suggests that higher efficiencies might be obtained with cathodes having a higher index n in the expression c_nT^n for the heat radiation per unit surface area, T being the absolute temperature and c_n a constant depending on the nature of the surface.

621.314.7 **2651**

Present Status of Transistor Development.—J. A. Morton. (*Bell Syst. tech. J.*, May 1952, Vol. 31, No. 3, pp. 411–442.) An account is given of progress in improving the reproducibility, reliability and performance of transistors. Types discussed include point-contact and n-p-n-junction transistors and phototransistors; characteristics are indicated by families of curves. Compared with thermionic valves, transistors are equal as regards reproducibility and superior as regards length of life and mechanical strength, but inferior as regards temperature effects, the upper limit of operation being 70–80°C, though the effect of this restriction is reduced because power consumption, and hence heating, is often low. As regards miniaturization, transistors are enormously superior. As regards applications, transistors can be considered seriously for pulse systems up to repetition rates of 1–2 Mc/s and for c.w. transmission at frequencies <1 Mc/s; for the range 1–100 Mc/s transistors should be considered only where very great importance is attached to smallness and reliability.

621.314.7 **2652**

A Method of Improving the Electrical and Mechanical Stability of Point-Contact Transistors.—B. N. Slade. (*RCA Rev.*, Dec. 1951, Vol. 12, No. 4, pp. 651–659.) Point-contact transistors embedded in resin suffer practically no change of electrical characteristics when subjected to severe impact and centrifuge tests; they are also largely unaffected by storage at extreme temperatures and by high humidity. Operation at low temperatures is satisfactory, but some changes of electrical characteristics are observed when operating at high ambient temperatures.

621.314.7 : 546.817.221 **2653**

Double-Surface Lead-Sulphide Transistor.—P. C. Banbury. (*Proc. phys. Soc.*, 1st March 1952, Vol. 65, No. 387B, p. 236.) The transistor voltage gain is found to increase with decreasing crystal thickness for both the type-A and the coaxial electrode configuration.

621.383 : 546.817.221 **2654**

Lead Sulphide Rectifier Photocells.—A. F. Gibson. (*Proc. phys. Soc.*, 1st March 1952, Vol. 65, No. 387B, pp. 214–216.) The properties of single-crystal cells at 290°, 195° and 90°K, are compared with those of similar PbTe cells (2655 below).

621.383 : 546.817.241 **2655**

Single-Contact Lead Telluride Photocells.—A. F. Gibson. (*Proc. phys. Soc.*, 1st March 1952, Vol. 65, No. 387B, pp. 196–214.) Of single-crystal cells studied at 90°K, only those of p-type show good rectification and marked photo-effects. Photosensitivity and time constant are determined by the total current at the contact point.

621.383.5 : 546.289 **2656**

A Large-Area Germanium Photocell.—J. I. Pantchechnikoff. (*Rev. sci. Instrum.*, March 1952, Vol. 23, No. 3, p. 135.) Brief details are given of a cell consisting basically of a Ge disk with a semi-transparent conducting metal film deposited on one face. Advantages of the arrangement as compared with the point-contact type cell are indicated and some characteristic data are given for a cell with a gold film on n-type Ge.

621.384.5 : 621.318.572 **2657**

The Development of a Multi-cathode Decade Gas-Tube Counter.—G. H. Hough. (*Proc. Instn elect. Engrs*, Part III, May 1952, Vol. 99, No. 59, pp. 166–167.) Summary only. As pulses are applied to the counter the glow discharge progresses round the array of ten cathodes, making one complete rotation for every ten pulses. Unidirectional progression is achieved by a special cathode producing asymmetrical priming which reduces the breakdown potential of the preferred adjacent transfer electrode. The tube operates with a supply voltage of 330 +20 V, developing at least 40 V across the 15-kΩ cathode resistors and counting aperiodically over the pulse repetition range of 0–20 000/sec.

621.385.029.64 : 168.2 **2658**

A Symbolism for Microwave-Valve Classification.—G. M. Clarke. (*Proc. Instn elect. Engrs*, Part III, March 1952, Vol. 99, No. 58, pp. 98–99.) Summary only, giving an outline of a proposed system.

621.385.032.213 **2659**

The Plasmatron, a Continuously Controllable Gas-Discharge Developmental Tube.—E. O. Johnson & W. M. Webster. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 645–659.) Full description of the construction and properties of a new type of valve using an independently generated gas-discharge plasma as a conductor between a hot cathode and an anode. See also 2869 of 1951 (Johnson).

621.385.032.213.1.027.5/.6 **2660**

Use of Thoriated-Tungsten Filaments in High-Power Transmitting Tubes.—R. B. Ayer. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 591–594.) An account of the development and use of Th-W filaments in transmitting valves such as the RCA-5671, RCA-5770 and RCA-5771, operating with anode voltages >5 kV. Typical self-supported multistrand Th-W filament assemblies are illustrated. Initial tests of type-RCA-207 valves fitted with Th-W filaments showed that grid currents were very sensitive to filament input, best performance being obtained at 517 W instead of the usual 1.144 kW for W filaments, a reduction of 55%. Oxygen-free high-conductivity Cu is used for the anodes of the above-mentioned valves, and Pt-coated Mo wires for the grids. Valve life in service has proved very satisfactory.

621.385.032.216 **2661**

Correlation of D.C. and Microsecond Pulsed Emission from Oxide Coated Cathodes.—F. A. Horak. (*J. appl. Phys.*, March 1952, Vol. 23, No. 3, pp. 346–349.) Ba-Sr oxide cathodes were prepared on base metals of pure Ni, Ni with 0·2% and with 4% Si, and Ni with 4·7% W. The results of emission measurements at intervals during zero-emission life tests show that the base metal affects the change of emission with time. The emission from cathodes on the W-Ni base remained nearly constant and was much higher than that for any of the other base metals.

621.385.032.216 **2662**

The Emission from Oxide-Coated Cathodes in an Accelerating Field.—D. A. Wright & J. Woods. (*Proc. phys. Soc.*, 1st Feb. 1952, Vol. 65, No. 386B, pp. 134–148.) "A theoretical treatment based on the existence of a space-charge zone immediately inside the coating. The charge in this zone is shown to vary with applied field and with current density, and with certain coating parameters. The variation in the charge leads to a variation in work function, and thereby to a dependence of emission on field strength, which is to be combined with the normal Schottky effect."

621.385.032.216 : 539.433.2 **2663**

Loss of Thermionic Emission in Oxide-Coated Cathode Tubes due to Mechanical Shock.—D. O. Holland, I. E. Levy & H. J. Davis. (*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 587–590.) Experimental results indicate that while many factors are involved in the effects of shock on cathode activity, evolution of gas from mica spacers is possibly the most important cause of emission reduction after shock. Increase of the number of mica spacers results in greater emission losses; some grades of mica are worse than others in this respect.

621.385.3 **2664**

Transit Time Oscillations in Triodes.—O. H. Critchley & M. R. Gavin. (*Brit. J. appl. Phys.*, March 1952, Vol. 3, No. 3, pp. 92–94.) Parasitic oscillations observed in disk-seal triodes over the wavelength range 6–20 cm are found to depend critically on the value of anode voltage and to occur at frequencies such that the cathode-grid transit time is about five-fourths of the oscillation period. The oscillations are similar to those previously observed by Llewellyn & Bowen in diodes (3155 of 1939).

621.385.83 **2665**

Axially Symmetric Electron-Beam and Magnetic-Field Systems.—L. A. Harris. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 700–708.) Theory is presented for long high-density beams in axial magnetic fields. Radial oscillations about an equilibrium radius are found to be always stable in the presence of a magnetic field, and can be made stable even without the field. Design formulae are given for two types of cathode, one having the emitting surface in a uniform magnetic field and giving a solid beam, the other having the emitting surface inside a magnetic screen and giving a tubular beam. Limited experimental results confirm most of the theory, and indicate the possibility of focusing without a magnetic field along the whole length of the beam.

621.385.831 **2666**

Space-Charge Waves in an Accelerated Electron Stream for Amplification of Microwave Signals.—Ping King Tien & L. M. Field. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 688–695.) Exact solutions are given for an idealized electron stream of infinite extent, accelerated or retarded uniformly through a space where d.c. space-charge effects are assumed to be neutralized by positive ions. The solution indicates that space-charge waves on a retarded stream grow in amplitude and can thus be used for amplifying microwave signals. The theory is relevant to the amplifying valves discussed previously [2068 of 1951 (Field et al.)]. Three amplifiers of this type have been constructed and are described. Measured values of gain at frequencies of about 3 kMc/s are in good agreement with calculated values.

621.385.832 **2667**

A Novel Type of Monoscope.—S. T. Smith. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 666–668.) Description of a c.r. tube with a rotationally symmetrical cuspidal target of polished Al shaped so that the variation with beam deflection of the secondary-emission current received by a conical collector corresponds to the variation of a received radar signal with angular displacement of the radar aerial.

621.385.832 **2668**

Fundamental Processes in Charge-Controlled Storage Tubes.—B. Kazan & M. Knoll. (*RCA Rev.*, Dec. 1951, Vol. 12, No. 4, pp. 702–753.) A comprehensive analysis is presented of the equilibrium potentials of insulated elements exposed to electron bombardment and to the action of light. The influence of the distribution of secondary-electron velocities is examined. Signal writing, reading and erasing processes are described and the abilities of the different methods to deal with half tones are discussed. Definitions are given of the terms used. 97 references, many of them annotated.

621.396.615.141.2 **2669**

Theory of the Magnetron Amplifier.—F. Lüdi. (*Z. angew. Math. Phys.*, 15th March 1952, Vol. 3, No. 2, pp. 119–128. In German.) Analytical treatment deriving an expression for the amplification factor. In contrast to the case of the conventional travelling-wave valve, amplification is possible when the electron velocity is considerably lower than the velocity of the travelling field. This is of particular interest for extremely short wavelengths.

621.396.615.141.2 : 621.316.727 **2670**

R.F. Phase Control in Pulsed Magnetrons.—E. E. David, Jr. (*Proc. Inst. Radio Engrs*, June 1952, Vol. 40, No. 6, pp. 669–685.) Discussion of magnetron oscillations started in the presence of an external r.f. exciting signal whose frequency is not greatly different from the steady-state frequency of the magnetron. Two methods of analysis are presented. In the first, quasi-steady-state starting is assumed. Solutions of the corresponding differential equation specify the phase of the oscillations as a function of the time interval after starting. In the second method, the oscillator is represented as a parallel RLC circuit shunted by a negative nonlinear conductance. Approximate solutions of the inhomogeneous van der Pol equation for this system are used to investigate the frequency and phase transients during starting, and also the distortion of the build-up envelope by the exciting signal. The initial conditions are in both cases established in terms of the ratio of exciting signal to preoscillation noise. The results of the two methods of analysis are essentially in agreement.

621.396.615.141.2(083.7) **2671**

Standards on Magnetrons: Definitions of Terms, 1952.—(*Proc. Inst. Radio Engrs*, May 1952, Vol. 40, No. 5, pp. 562–563.) Standard 52 IRE 7S1.

MISCELLANEOUS

621.3.015.7(083.71/.72) **2672**

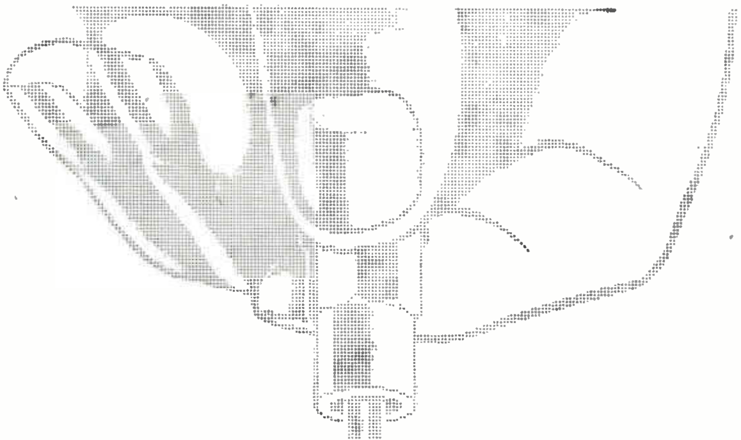
Technical Vocabulary.—(*Onde élect.*, March 1952, Vol. 32, No. 300, pp. 113–114.) A list, prepared by the Vocabulary Commission of the S.N.I.R., of general terms relating to pulse technique, with definitions and in some cases English equivalents.

621.396.6 + 621.397.6 + 621.385 **2673**

New Radio Components in the World Market.—M. Alixant. (*Radio tech. Dig., Édn franç.*, 1952, Vol. 6, Nos. 1–3, pp. 3–62, 89–108 & 139–149.) Classified review listing the characteristics of new circuit components, loudspeakers, microphones, sound recording apparatus, television equipment and valves.

621.396 **2674**

Advances in Electronics, Vol. 3. [Book Review]—L. Marton (Ed.). Publishers: Academic Press, New York, 357 pp., $7.50. (*Brit. J. appl. Phys.*, Nov. 1951, Vol. 2, No. 11, pp. 335–336.) Vol. 2: 2006 of 1950.



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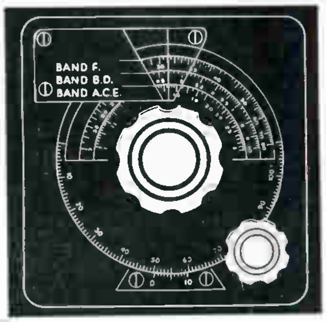

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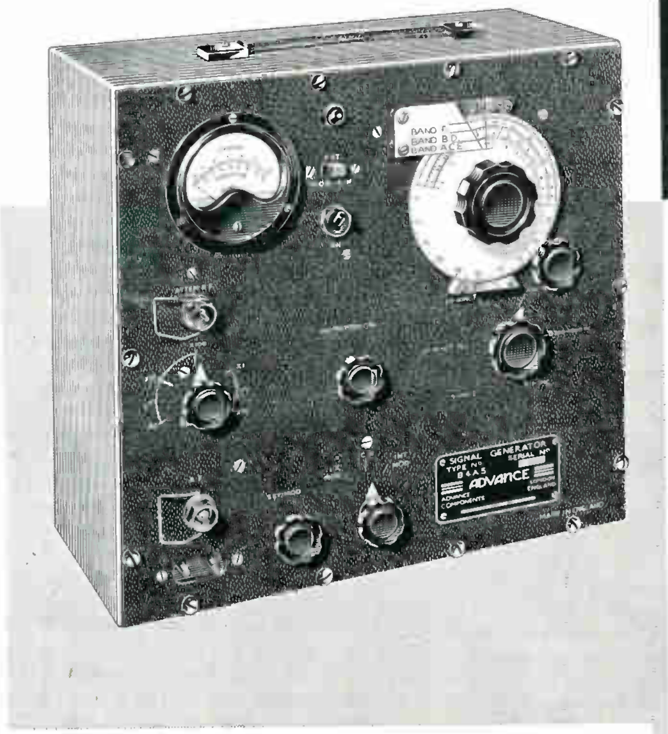

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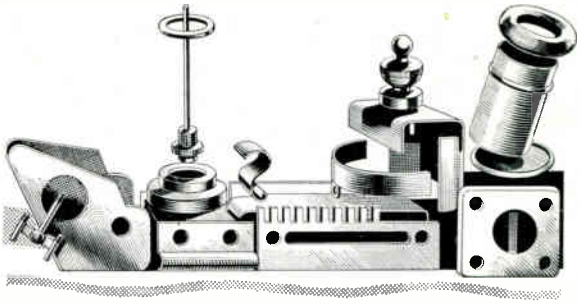

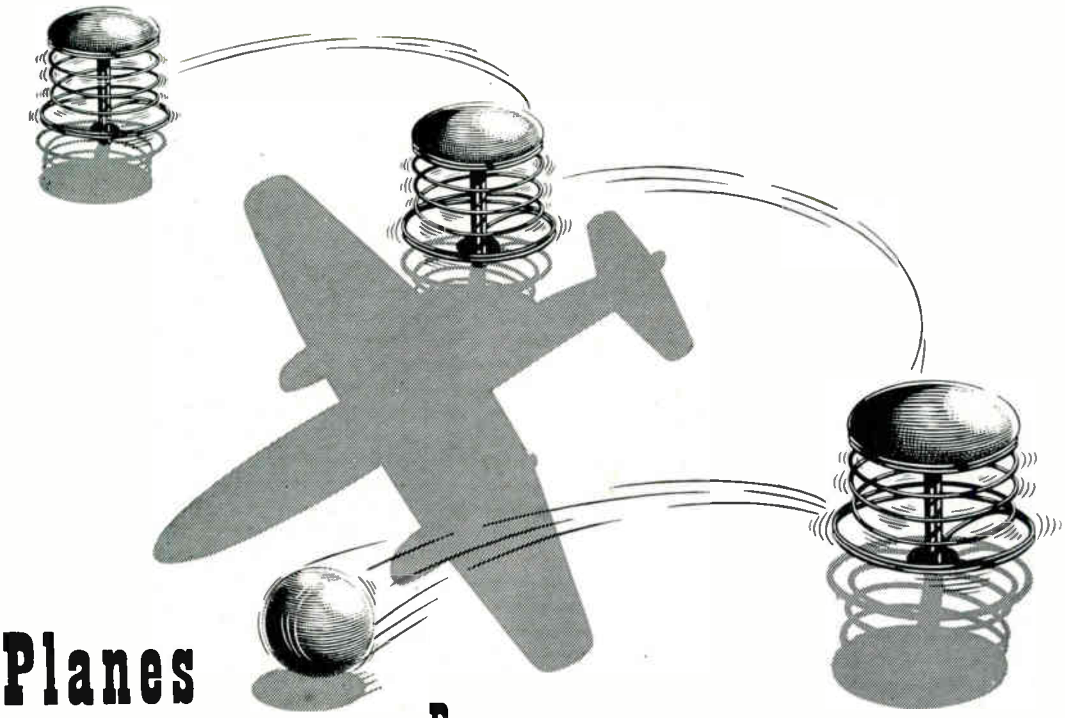

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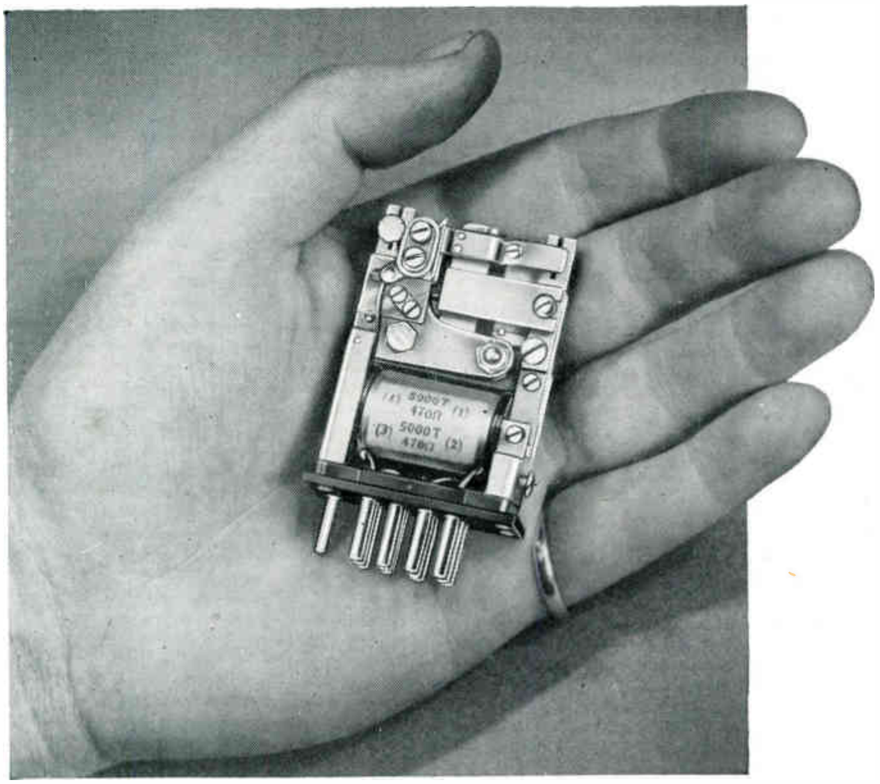

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Plug or solder tag base optional.

Dimensions—(With cover. Excluding connecting pins.) $2\frac{3}{16}$ *ins. high.* $1\frac{7}{16}$ *ins. wide.* $\frac{3}{4}$ *in. deep. Weight (including socket)* 4.8 *oz.* (137 *gm.*)

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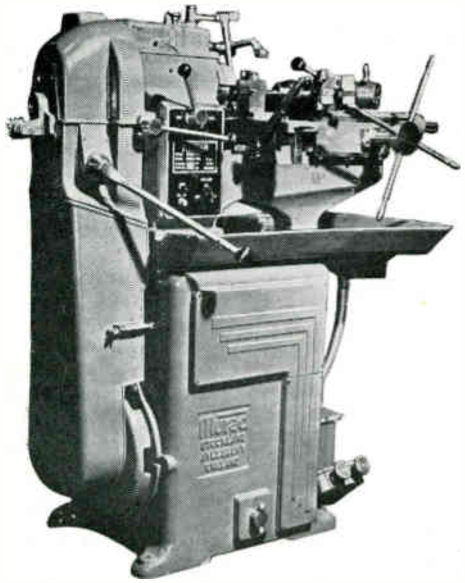
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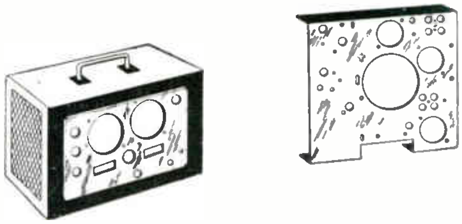

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A course of thirteen lectures on "The Fundamentals of Pulse Techniques" will be given by specialist lecturers on Monday evenings, commencing on Monday, 6th October at 7 p.m. Further particulars from the Secretary, Borough Polytechnic, Borough Road, London, S.E.1.

APPOINTMENTS—The engagement of persons answering these advertisements must be made through the local office of the Ministry of Labour and National Service, etc., if the applicant is a man aged 18-64 or a woman 18-59 inclusive, unless he or she or the employer is excepted from the provisions of The Notification of Vacancies Order, 1952.

Experienced men (ex-Service radar mechanics preferred) are required for duties in the electronics division of Saunders-Roe, Ltd. Applicants should be capable of intelligent assembly and wiring of a wide variety of electronic apparatus from circuit diagrams. Write, giving details of experience, age, etc., to the Personnel Officer, Saunders-Roe, Ltd., East Cowes, Isle of Wight.

FERRANTI, LTD., Moston, Manchester, have vacancies for:—

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(2) Mechanical/Electrical Engineers for development work on (*a*) and (*b*) above. Preference will be given to candidates who can show evidence of practical achievement.

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Please quote reference H.N.

E. K. COLE, LTD. (Malmesbury Division), invite applications from Electronic Engineers for permanent posts in Development Laboratories engaged on long-term projects involving the following techniques:—

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Wireless Station Superintendent (Temporary) required by the Gold Coast Government Posts and Telegraphs Department for two tours of 18 to 24 months in the first instance. Commencing salary, according to qualifications and experience in the consolidated scale £955 rising to £1,180 a year, with gratuity of £25 or £37 10s. 0d. according to salary, for each completed period of three months' service. Outfit allowance £60. Liberal leave on full salary. Free passages. Candidates must possess a Higher National Certificate in Electrical Engineering or equivalent, and have had practical experience in two or more of the following fields: V.H.F. link systems, H.F. communication network, frequency shift keying and teleprinter maintenance, V.H.F. and H.F. direction finding systems, aeronautical navigation aids (ground), manufacture of light engineering equipment. Apply at once by letter, stating age, full names in block letters, and full particulars of qualifications and experience, and mentioning this paper, to the Crown Agents for the Colonies, 4 Millbank, London, S.W.1, quoting on letter M.29100B. The Crown Agents cannot undertake to acknowledge all applications and will communicate only with applicants selected for further consideration.

An experienced graduate is required by the General Electric Co., Ltd., for work at their Stanmore laboratories for responsible work concerned with the development of specialised test equipment for airborne radar. An original approach to the problem is necessary and a knowledge of microwave techniques or circuit design is essential. Apply to the Staff Manager (Ref. GBLC/S/508), Research Laboratories of The General Electric Co., Ltd., Wembley, Middlesex, stating age, qualifications and experience.

Engineer or physicist experienced in radar is required for work in connection with flight trials of airborne and radar equipment. Degree or Higher National Certificate required. Experience of aircraft and flying desirable, but not essential. Apply in writing to the Staff Manager (Ref. GBLC/S/994), Research Laboratories of The General Electric Co., Ltd., North Wembley, Middlesex, stating age, qualifications and experience.

General Electric Co. have two vacancies for graduates for work at Stanmore: (*a*) an experienced man is required to take major responsibility for the design and operation of system test apparatus to be used in connection with airborne radar equipment, (*b*) physicist or engineer for work on electronic simulators. Apply in writing to the Staff Manager (Ref. GBLC/S/995), Research Laboratories of The General Electric Co., Ltd., Wembley, Middlesex, stating age, experience and qualifications.

Department of Scientific and Industrial Research. Applications are invited for an unestablished experimental officer post in the radio research organisation at Teddington, Middlesex, for abstracting scientific and technical articles on radio research and development. Candidates should possess a Higher National Certificate or equivalent qualifications and have a considerable knowledge and experience of some branch of radio research or development. The ability to read technical French and German would be useful but not essential. The salary range for men is at present £628-£786. Candidates should be at least 26 and preferably under 31, but older candidates are not excluded. Forms obtainable from Ministry of Labour and National Service, Technical and Scientific Register (K), Almack House, 26 King Street, London, S.W.1, Quoting Ref. D268/52A.

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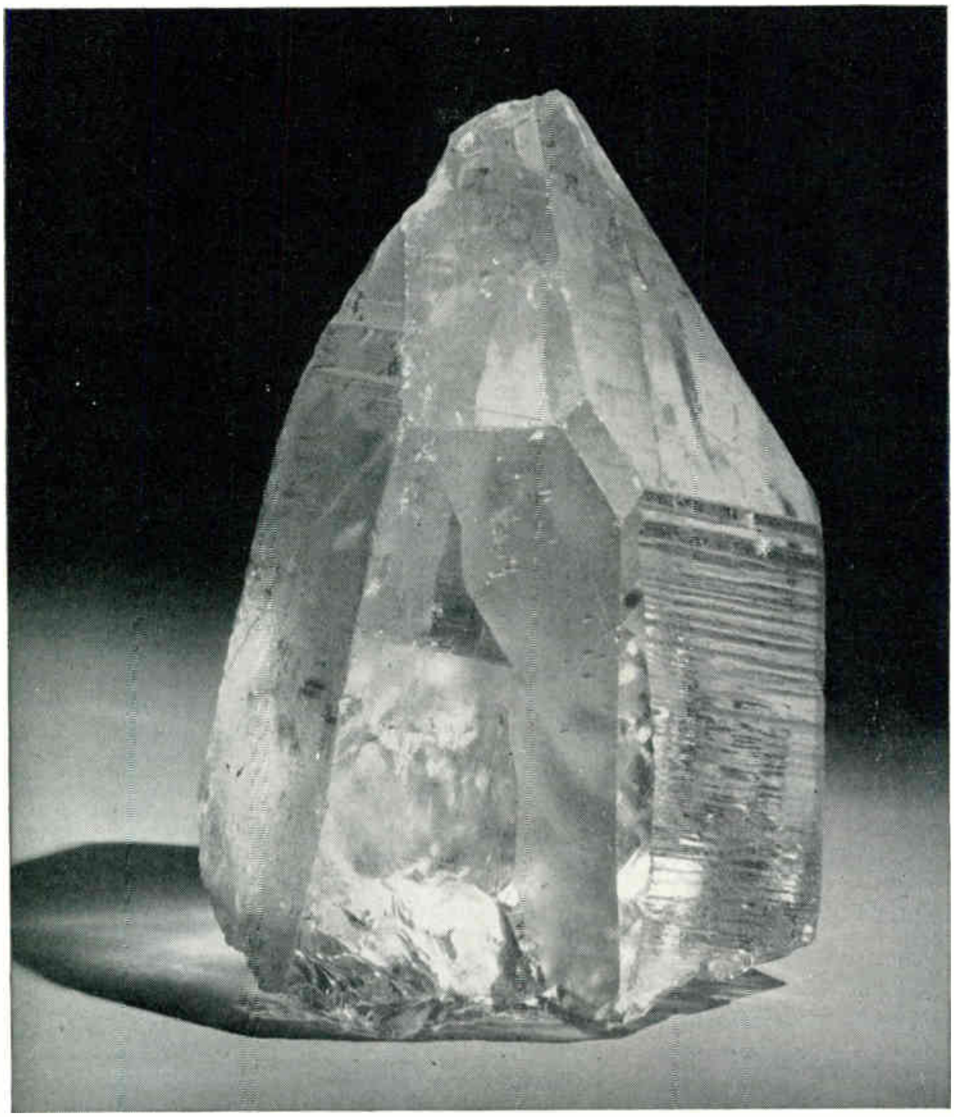
(A) Diesel-Electric Mechanic (M.29389.B) and **(B) Wireless-Operator Mechanic (M.29387.B)** required for the Falkland Islands Dependencies Survey for one tour of 18 or 30 months in the first instance. Salary according to qualifications and age in scale £250 rising to £415 a year. Duty allowance of £40 a year. Quarters, subsistence, clothing and liberal routine canteen stores are provided free of charge while serving in Dependencies; it is possible for officers to save almost all emoluments. Liberal leave on full salary. For both posts candidates should preferably be single. For post (A) they must possess a general working knowledge of electricity, and be capable of running and maintaining small diesel generating sets, with associated switch-boards, accumulators, etc. For post (B) candidates must be able to transmit and receive morse at 25 words a minute (plain language or code) and be capable of elementary maintenance of wireless transmitting and receiving equipment. Apply at once by letter, stating age, full names in block letters, and full particulars of qualifications and experience, and mentioning this paper, to the Crown Agents for the Colonies, 4 Millbank, London, S.W.1, quoting on letter the reference number against the appointment for which application is made. The Crown Agents cannot undertake to acknowledge all applications and will communicate only with applicants selected for further consideration.



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

Electronic Engineers with several years research or development experience are invited to apply for posts with a well-established company engaged on the development of precision laboratory instruments. Applicants should preferably possess an Honours Degree or equivalent qualifications in physics or light electrical engineering, although this is not essential as considerable practical experience is equally acceptable. The appointments are of a permanent nature for engineers of ability who are capable of developing new projects to the prototype stage, and offer scope for the exercise of individual initiative. The work is of absorbing interest and covers a wide range of electronic instruments. Salaries are commensurate with qualifications and experience. Applications should be made in writing to the Personnel Manager, Furzehill Laboratories, Ltd., Boreham Wood, Herts.

The General Electric Co., Ltd., Brown's Lane, Coventry, have vacancies for Development Engineers, Senior Development Engineers, Mechanical and Electronic, for their Development Laboratories on work of national importance. Fields include microwave and pulse applications. Salary range £400-£1,250 per annum. Vacancies also exist for Specialist Engineers in component design, valve applications, electro-mechanical devices and small mechanisms. The Company's Laboratories provide excellent working conditions with social and welfare facilities. Superannuation Scheme. Assistance with housing in special cases. Apply by letter stating age and experience to The Personnel Manager (Ref. CHC.).

Vacancies exist for Senior and Junior Electronic Engineers, on work in connection with the electronic measurement of physical variables and associated problems. This consolidation and expansion of a young department offers scope for men with enterprise and ability. Applications, stating age, full details of qualifications, experience and salary required, should be addressed to the Personnel Officer, Saunders-Roe, Ltd., East Cowes, I.O.W.

Senior Electronic Engineer required. Experience of Helicopter instrumentation and of analogue computors would be an advantage. Apply, stating experience, age, etc., to the Personnel Officer, Saunders-Roe, Ltd., Southampton Airport, Eastleigh, Hants.

The English Electric Co., Ltd., Luton, invites applications for permanent posts in a laboratory engaged in development work involving radar techniques. Senior and junior positions are available to candidates possessing suitable qualifications and a knowledge of one or more of the following: (1) centimetric systems and measurements, (2) radar or television receiver practice, (3) mechanical layout and design work in connection with the above. Salaries according to qualifications and experience in range £450 to £1,000. The laboratories are new and pleasantly situated. The company also encourages further study in the case of juniors. Please write giving full details and quoting reference "English Electric 4561," to Westminster Employment Exchange, Chadwick Street, London, W.1.

The English Electric Valve Company, Chelmsford, Essex, has several attractive vacancies for graduates to undertake research and development work on vacuum tubes. Applications from graduates who have recently qualified as well as those with industrial or research experience will be considered. Please write, giving full details, quoting reference 419E to Central Personnel Services, English Electric Co., Ltd., 24-30 Gillingham Street, London, S.W.1.

Technical Commercial Engineer required by large electrical manufacturers for their radio export department. Candidates should be between the ages of 25/35 and must have an engineering or science degree, and technical experience, preferably applied to radio receivers. Appointment will be in the London area and successful candidate will be primarily responsible for the technical aspects and qualities of receivers in production for export. Write, giving fullest details including age, education, technical qualifications and previous experience to Box 2177, c/o *Wireless Engineer*.

Large valve manufacturing company requires for its service department in the Southern London area an assistant equipment maintenance engineer for the maintenance of valve and cathode ray tube test boards, and also a projection television service engineer for the servicing of projection units. Write, giving full details to Box 2178, c/o *Wireless Engineer*.

R.F. Engineer required for South-West London area to take charge of waveguide development laboratory. Applicants must have experience of the development of X-band waveguide components up to and including full production drawings. Applicants should state full details of qualifications and experience, age and salary required. Ref. ME, Box 2179, c/o *Wireless Engineer*.

Carrier Telephone Engineer, several years' experience, required by American company with sales branch in Southern Europe for sales and installation work. Young, preferably bachelor, considerable travelling involved. Box 2180, c/o *Wireless Engineer*.

Electrical Engineers with an interest in servo-systems and small mechanical devices are required by the research laboratories of The General Electric Co., Ltd., Wembley, Middlesex, for work at Stanmore. University degree or H.N.C. is essential, plus some experience in the development of small mechanisms. Write to the Staff Manager (Ref. GBLC/S/579), stating age and record.

Graduate Physicists and Engineers are required at the G.E.C. Stanmore Laboratories for work concerned with (*a*) electronic circuitry, (*b*) electronic simulators, and (*c*) magnetic amplifiers or small power electric motors. Experience in one of these fields will be an advantage. Apply to the Staff Manager (Ref. GBLC/S/580), Research Laboratories of The General Electric Co., Ltd., Wembley, Middlesex, stating age, qualifications and experience.

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0—5 volts	0—25 ,,
0—25 ,,	0—100 ,,
0—100 ,,	0—250 ,,
0—250 ,,	0—500 ,,
0—500 ,,	

D.C. Current	Resistance
	0—20,000 ohms
0—2·5 milliamps	0—100,000 ,,
0—5 ,,	0—500,000 ,,
0—25 ,,	0—2 Megohms
0—100 ,,	0—5 ,,
0—500 ,,	0—10 ,,

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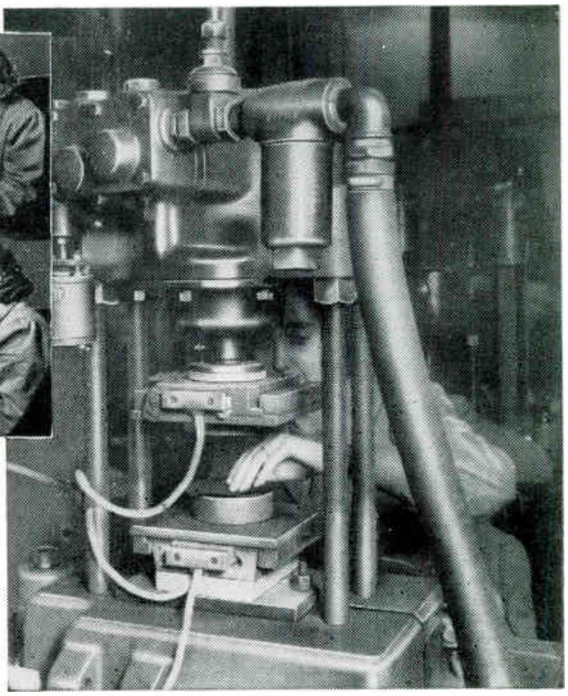

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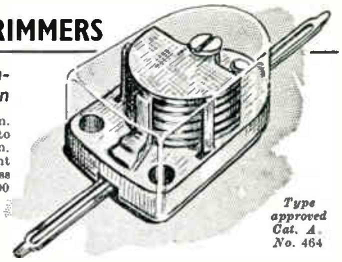

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