ELECTRONIC & RADIO ENGINEER

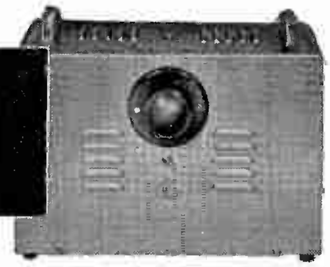
Incorporating **WIRELESS ENGINEER**

In this issue

Three shillings
and sixpence

JUNE 1957 Vol 34 *new series* No 6

A-C AUTOMATIC VOLTAGE REGULATORS
39 BASIC TYPES IN 6 DESIGN SERIES



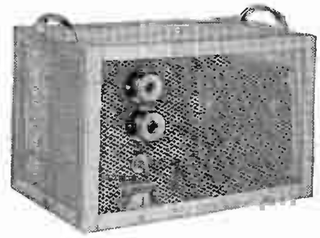
BMVR - 1725

WIDEST RANGE IN THE WORLD?

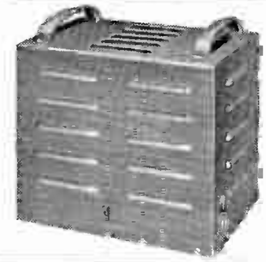
So far as we are aware, our range of A.C. Automatic Voltage Stabilisers is the largest in the World. We have a very wide range of standard models, single-phase patterns ranging from 200 VA to about 30 kVA (3-phase types up to about 90 kVA). There are 39 basic types, in six distinct design series, and all are available in standard form or as tropicalised instruments. We feel that on this account there can be few, if any requirements covering Stabilisers that we are not in a position to meet economically, efficiently and promptly.

Here are very brief details of the six main series, in handy tabular form: cut this ad. out and use it as a Buying Guide; but please remember that if you do not see *exactly* what you require a written enquiry will probably reveal that we have a "special" to suit, or that the answer is under development. New stabilisers are regularly being added to our range. Several are at the very advanced development stage now—and we do design "specials". One such "special" (AM type 10D/20161) is illustrated (Illustrations not to scale). Nearly 100 have been supplied to Murphy Radio Ltd. for incorporation in equipment supplied by them to the Air Ministry for use on a chain of Radar Marker Beacons. 45 in slightly differing form are currently being made by us for the Air Ministry for another Radar Chain.

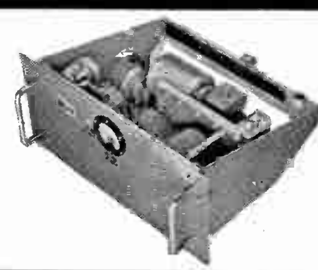
For complete data request our new 32-page illustrated Catalogue Technical Manual, C.L.L. Form S-574.



BAVR - 1000 & BAVR - 1000-E



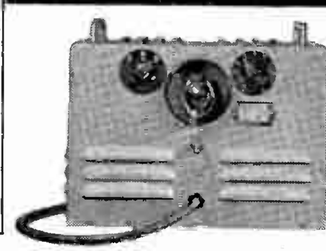
BMVR - 7000 - Series & TCVR - 7000 - Series



BMVR - 2750 - S58 (AM Ref. 10D/20161)

DESIGN SERIES	ASR	ATC	BAVR	BAVR-E	BMVR	TCVR
Input Voltage "Swing"	−10% to +5%	−20% to +10%	−10% to +5%	−10% to +5%	Depends on power: typical is from −19% to +8.5%	
Output Voltage Stability	±2½%	±5%	±0.15%	±0.15%	Usually ±0.5%	Usually ±0.5%
Change due to load (0-100%)	NEGLIGIBLE		±2.0%	±0.3%	NIL	NIL
Harmonics Generated	NIL	NIL	YES	YES	NIL	NIL
Response Speed	PRACTICALLY INSTANTANEOUS AVERAGING				1 V/Sec.	40V/Sec.
	2-3 CYCLES		1 CYCLE			
Power Ratings	1150VA 2300VA	575VA 1150VA	200VA 500VA 1000VA	200VA 500VA 1000VA	1600VA to 30kVA (18 models)	1600VA to 12kVA (11 models)
Basic Prices *	£24 to £34	£24 to £34	£50 to £79	£59 to £88	£75 to £237	£91 to £144

* From May 1st 1956, subject to 7½% increase.



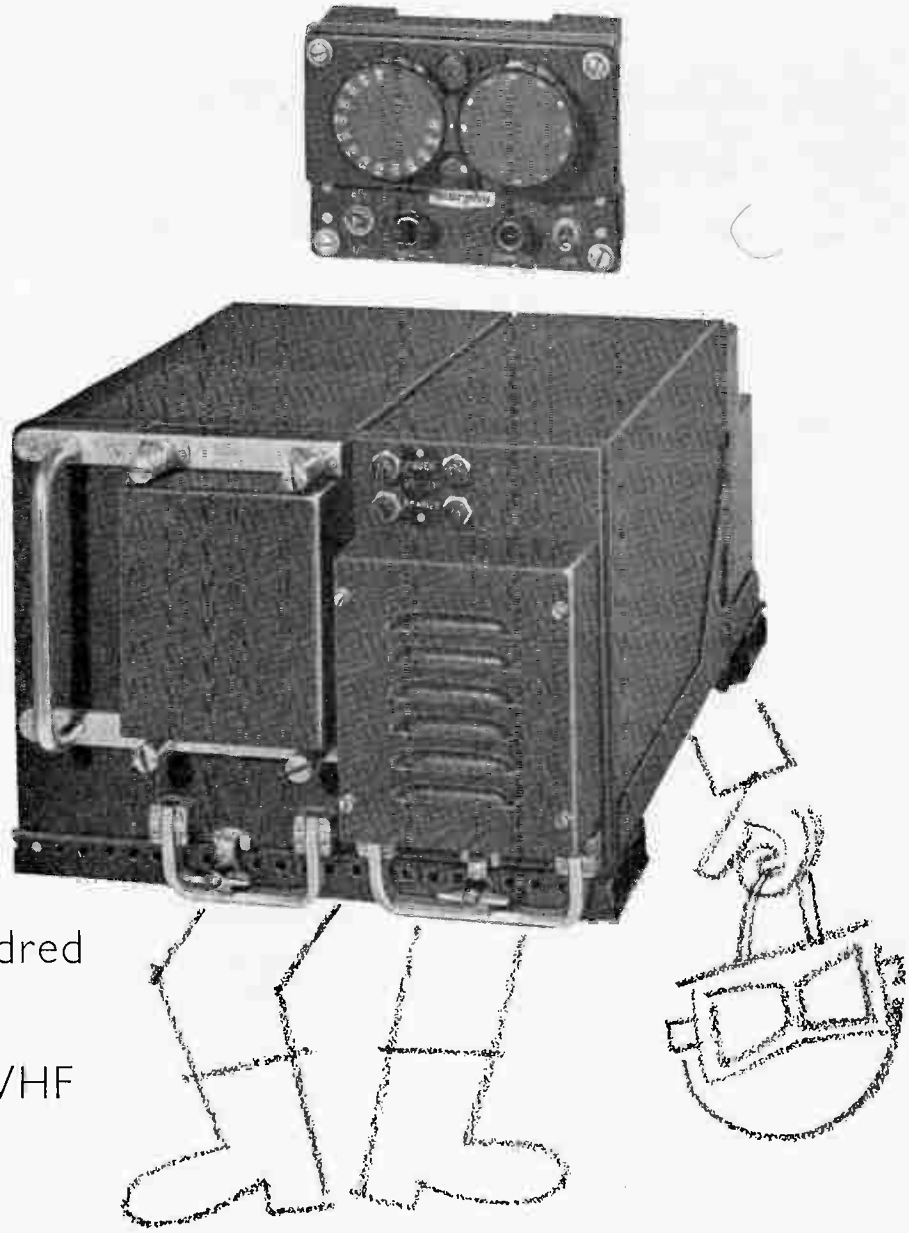
BMVR - 2750/VV & TCVR - 2750/VV

Claude Lyons Ltd.

STABILISER DIVISION

ASR - 1150 & ATC - 575.

HODDESDON · ENGLAND · TEL: HODDESDON 3007 (4 LINES) · 'GRAMS: MINMETKEM, HODDESDON



Meet Mr. Three Hundred (or MR300 for short) —the latest style in VHF from ***murphy***

What exactly is it? — Murphy MR300 is a VHF transmitter/receiver that offers radio telephone facilities on 44 spot frequencies anywhere in the 118-132 mc/s band. It is suitable for all types of civil aircraft, being compact, light in weight, fully tropicalised, and capable of operation up to 40,000 feet.

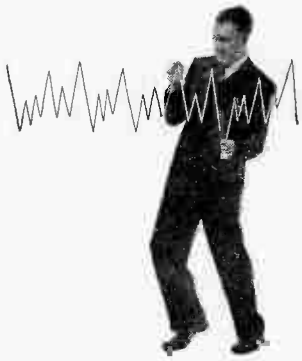
What does it consist of? — Murphy MR300 comprises two main units and a control unit. The transmitter/power unit TP301 and the receiver unit R302 are separately housed in cabinets designed for mounting in standard RCEEA racking. A common backplate connects these units with the control unit. The latter, VFC305, is housed in a light alloy case and contains all the operating controls. Both transmitter and receiver are controlled from the same crystal oscillator and tuning is automatic when switching from one channel to another.

How can you find out more about it? — Write to us and we will gladly send you full technical details.

keep in touch with ***murphy***

MURPHY RADIO LIMITED (ELECTRONICS DIVISION), WELWYN GARDEN CITY, HERTS.

CRC 34E



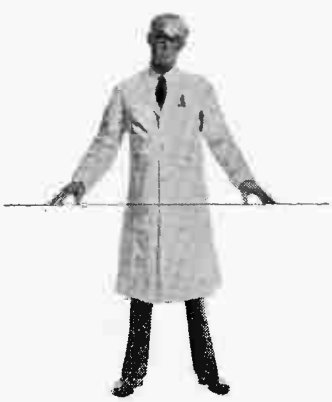
A Mains Voltage Fluctuation problem in Absorption Analysis

A Unicam type SP.600 Spectrophotometer in use with an 'Advance' C.V.T.

The spectrophotometer employs a particular optical/electronic system in which a light source, photocells and special amplifier play a vital part. Vital, because it is upon their correct performance characteristics that the accuracy of the instrument depends.

But their correct performance, in turn depends upon a stable supply voltage. How is this achieved?

. . . straightened out by *Advance*



In the Unicam SP.600 Spectrophotometer illustrated the tungsten lamp, and valve heaters in the amplifier are supplied from the mains through an 'Advance' Constant Voltage Transformer (seen on the right). As a result the accuracy of the instrument is unaffected by fluctuating supply voltage.

'Advance' Constant Voltage Transformers provide a.c. voltage stabilisation of $\pm$ 1% for input variations of up to $\pm$ 15% at maximum load. For power requirements from 4 to 6000 watts, they are automatic and contain no moving parts.

Technical details available in Folder R28 sent on request.

CVT

CONSTANT VOLTAGE TRANSFORMERS

ADVANCE COMPONENTS LIMITED

ROEBUCK ROAD · HAINAULT · ILFORD · ESSEX. Telephone: HAInault 4444

GD13

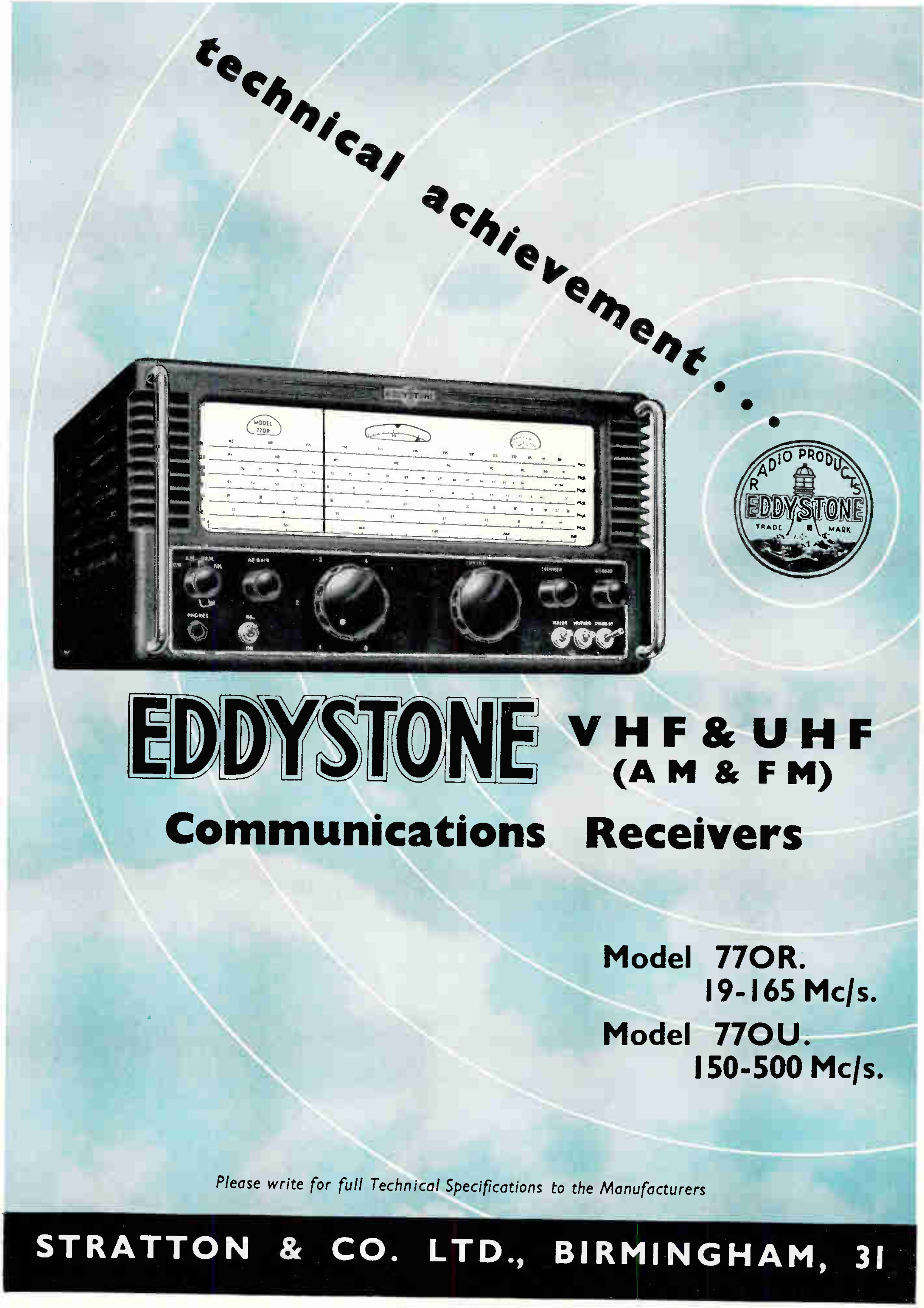
There's a size for every job in the S.P. range of nickel metallised bushes

Please write for Catalogue No. 47

STEATITE & PORCELAIN PRODUCTS LTD.

STOURPORT ON SEVERN, WORCS · Telephone: Stourport 2271 Telegrams: Steatain, Stourport.

S.P.50

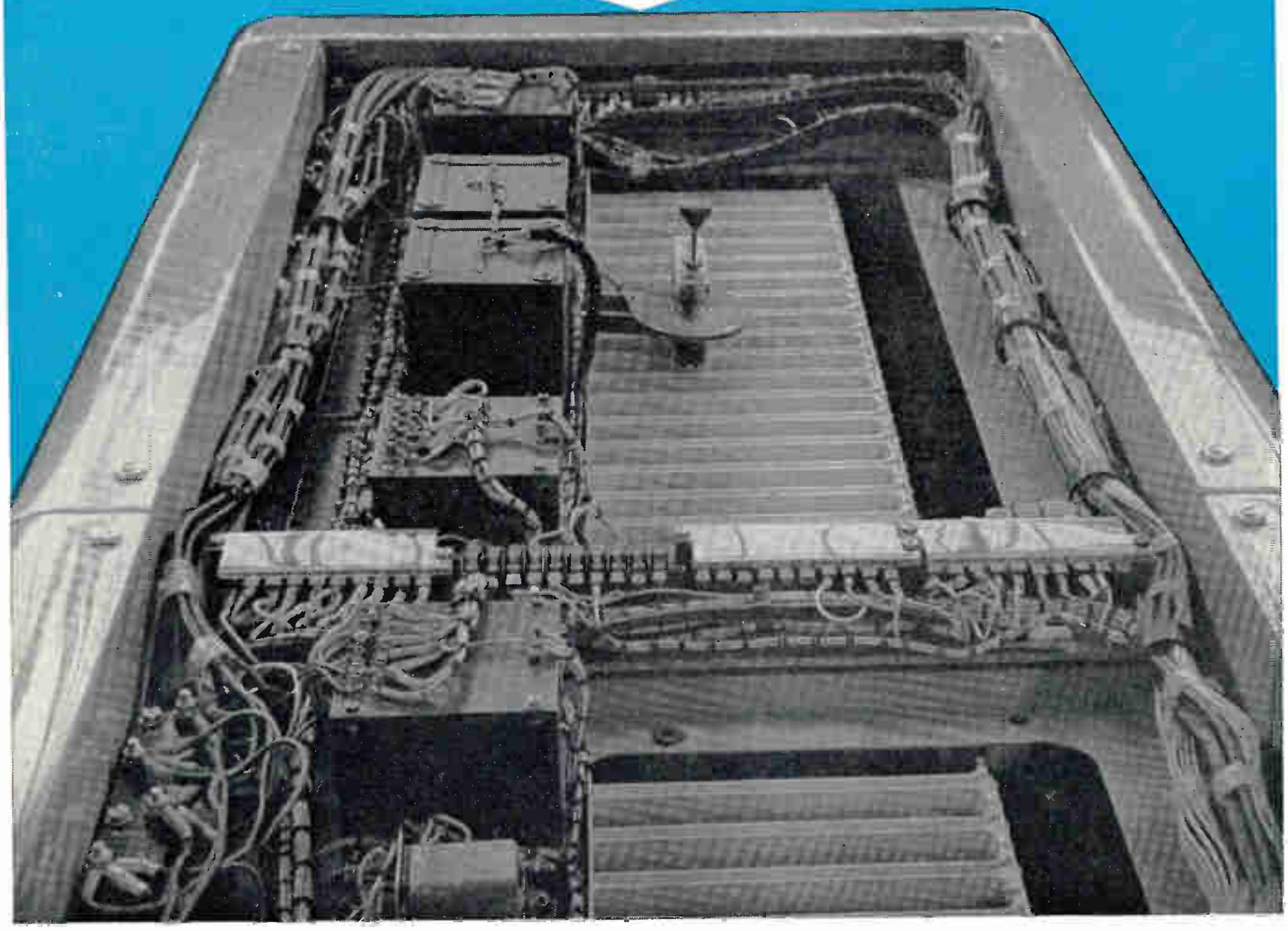

technical achievement . . .
RADIO PRODUCTS
EDDYSTONE
TRADE MARK
EDDYSTONE
VHF & UHF
(AM & FM)
Communications Receivers
Model 770R.
19-165 Mc/s.
Model 770U.
150-500 Mc/s.
Please write for full Technical Specifications to the Manufacturers
STRATTON & CO. LTD., BIRMINGHAM, 31

Plessey preformed wiring

. . . helps industry keep pace with progress

As engineering development gathers momentum, wiring becomes increasingly complex—and the need for specialist service in this field becomes self-evident. No longer is it usually practicable or economic to involve yourself in the production of the wiring systems your equipment requires. British engineering industries rely on Plessey preformed wiring for products and projects ranging from computers and teleprinters to ships, diesel-electric trains, and aircraft.

Plessey preformed wiring is used in the Ferranti 'Pegasus' Computer.
Photograph by courtesy of Ferranti Limited.

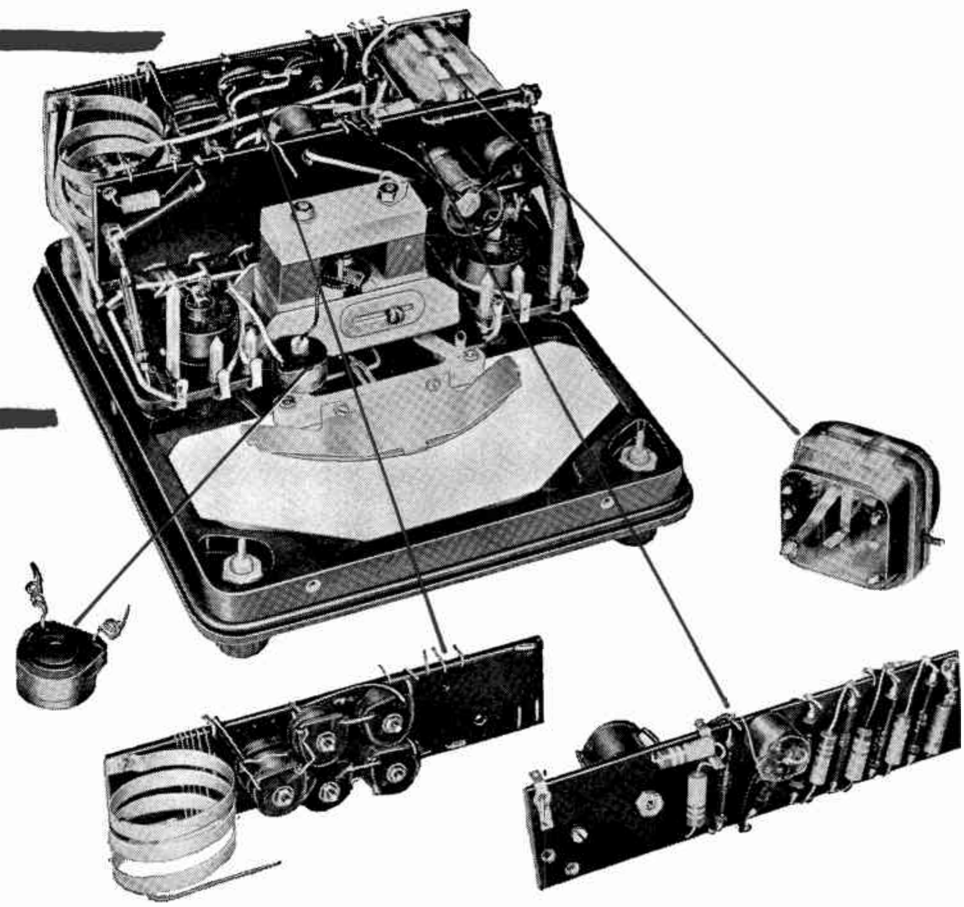


AIRCRAFT & AUTOMOTIVE GROUP · THE PLESSEY COMPANY LIMITED · ILFORD · ESSEX

PB11

The famous Avometers are possibly the most widely used instruments of their type in the World and have an excellent record of service under all climatic conditions, even at arctic temperatures. In tropical climates, however, there is a constant risk of derangement due to humidity, heat, and the development of fungoid growths. To meet these conditions, the manufacturers of Avometers have produced special types known as Models 7X, 8X and 8(S)X, which are suitable for continuous use in any extremes of heat or cold. In these instruments, certain components are potted in Araldite epoxy resin, which has the advantages of remarkable adhesion to metals, ceramics, etc., good dielectric properties, low shrinkage, resistance to moisture and extremes of climate, and complete freedom from micro-biological attack.

Poles apart



Araldite epoxy resins have a remarkable range of characteristics and uses.

They are used

- ★ **for bonding metals, porcelain, glass, etc.**
- ★ **for casting high grade solid insulation**
- ★ **for impregnating, potting or sealing electrical windings and components**
- ★ **for producing glass fibre laminates**
- ★ **for producing patterns, models, jigs, tools, etc.**
- ★ **as fillers for sheet metal work**
- ★ **as protective coatings for metal, wood and ceramic surfaces**

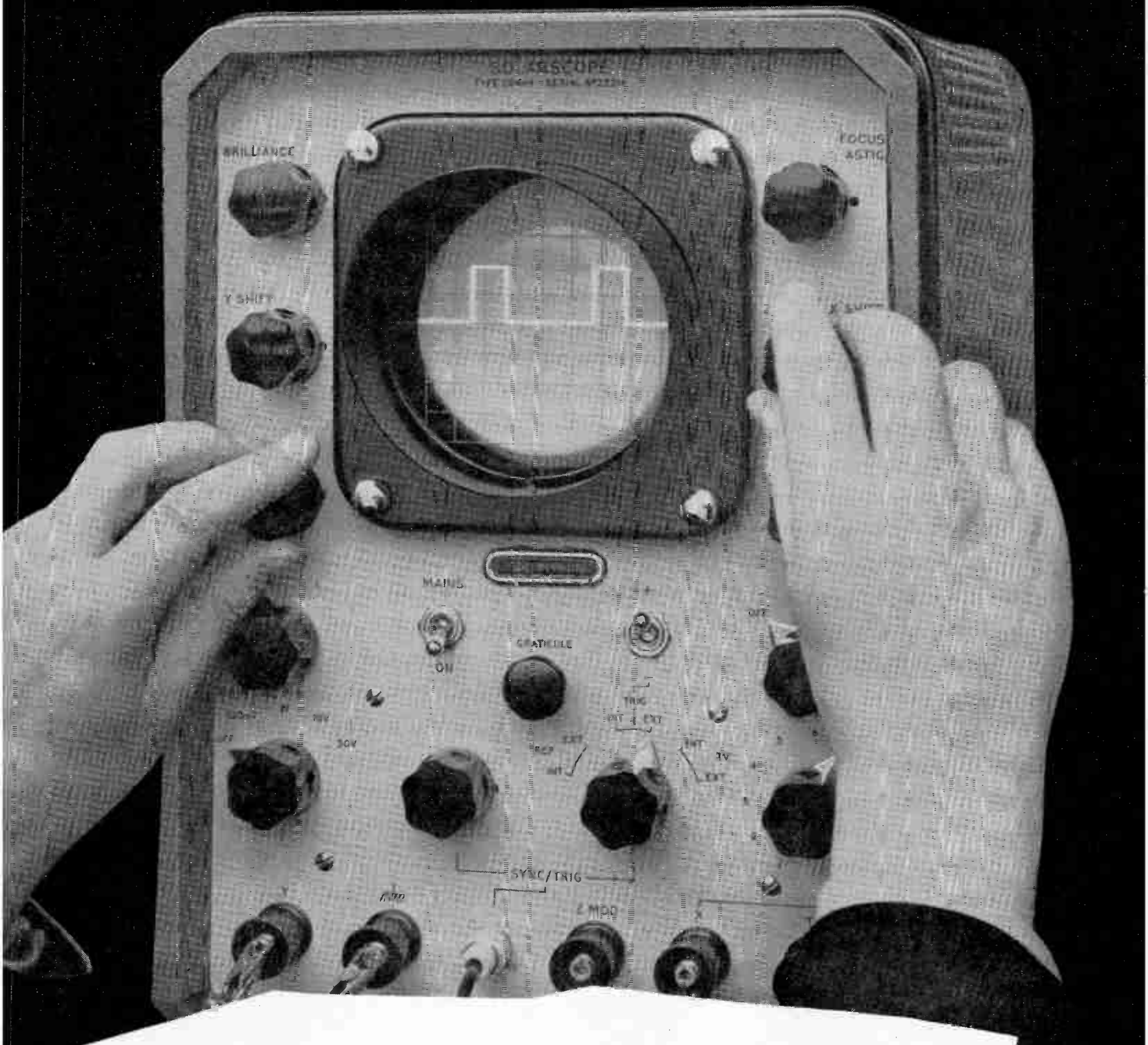
Araldite *epoxy resins*

Araldite is a registered trade name

Aero Research Limited *A Ciba Company · Duxford · Cambridge · Telephone: Sawston 2121*

AP316


IN CONTACT . . .
The unfailing accuracy required of radio equipment in shore, air and sea communications necessitates the use of the most efficient and reliable components. Experience shows that G.E.C. Quartz Crystal Units are unexcelled in consistent accuracy.
G.E.C.
QUARTZ CRYSTAL UNITS
SALFORD ELECTRICAL INSTRUMENTS LTD.
PEEL WORKS, SILK STREET, SALFORD 3, LANCS
A subsidiary of the
GENERAL ELECTRIC COMPANY LTD.
OF ENGLAND



High performance . . . wide applications . . . truly portable

In the Solarscope CD 614 we have included all the valuable features of heavier and more expensive oscilloscopes, while producing a truly portable instrument at an economical price. It is particularly suited for radio communication, radar, TV and applications involving pulse work and transient investigations.

BRIEF SPECIFICATION

NOMINAL BANDWIDTH
1 c/s — 9 Mc/s ± 1 Mc/s for 3 db down

SENSITIVITY CALIBRATION
By a 50 c.p.s. square wave

EXPANSION
10 diameters nominal

CALIBRATION
By 0·1 μS, 1μS, and 10 μS markers ± 5%

TIME BASE
10 c.p.s. — 200 Kc/s
Trigger from TV frame block

THE SOLARTRON ELECTRONIC GROUP LTD.

THAMES DITTON · SURREY   TELEPHONE: EMBerbrook 5522 · CABLES: SOLARTRON, THAMES DITTON

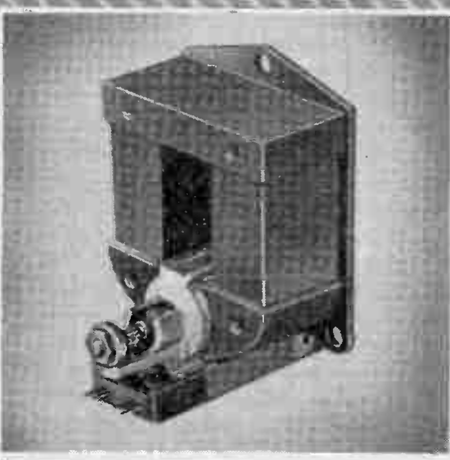

ELECTRONICS RESEARCH
Interesting jobs for young scientists
Attractive research jobs for able and ambitious young scientists are available in Hollerith electronics. Original work is encouraged. Laboratories are well-equipped for electronics research. Salaries are excellent, *and prospects in this expanding industry are outstanding.*
Senior men will operate as group leaders. Postgraduates are required as group members. Groups are small and highly specialised. Applicants will appreciate the considerate employment, excellent pension scheme, help with housing, and other amenities that go with these posts.
Hollerith electronic computers
Write to the Head of Research,
The British Tabulating Machine Co. Ltd.,
Electronics Research Laboratory,
Gunnels Wood Road,
Stevenage, Herts.

ELECTRO METHODS LTD

OF STEVENAGE

BRITAIN'S FOREMOST DESIGNERS AND MANUFACTURERS OF

LOW-INERTIA MOTORS AND TACHO GENERATORS



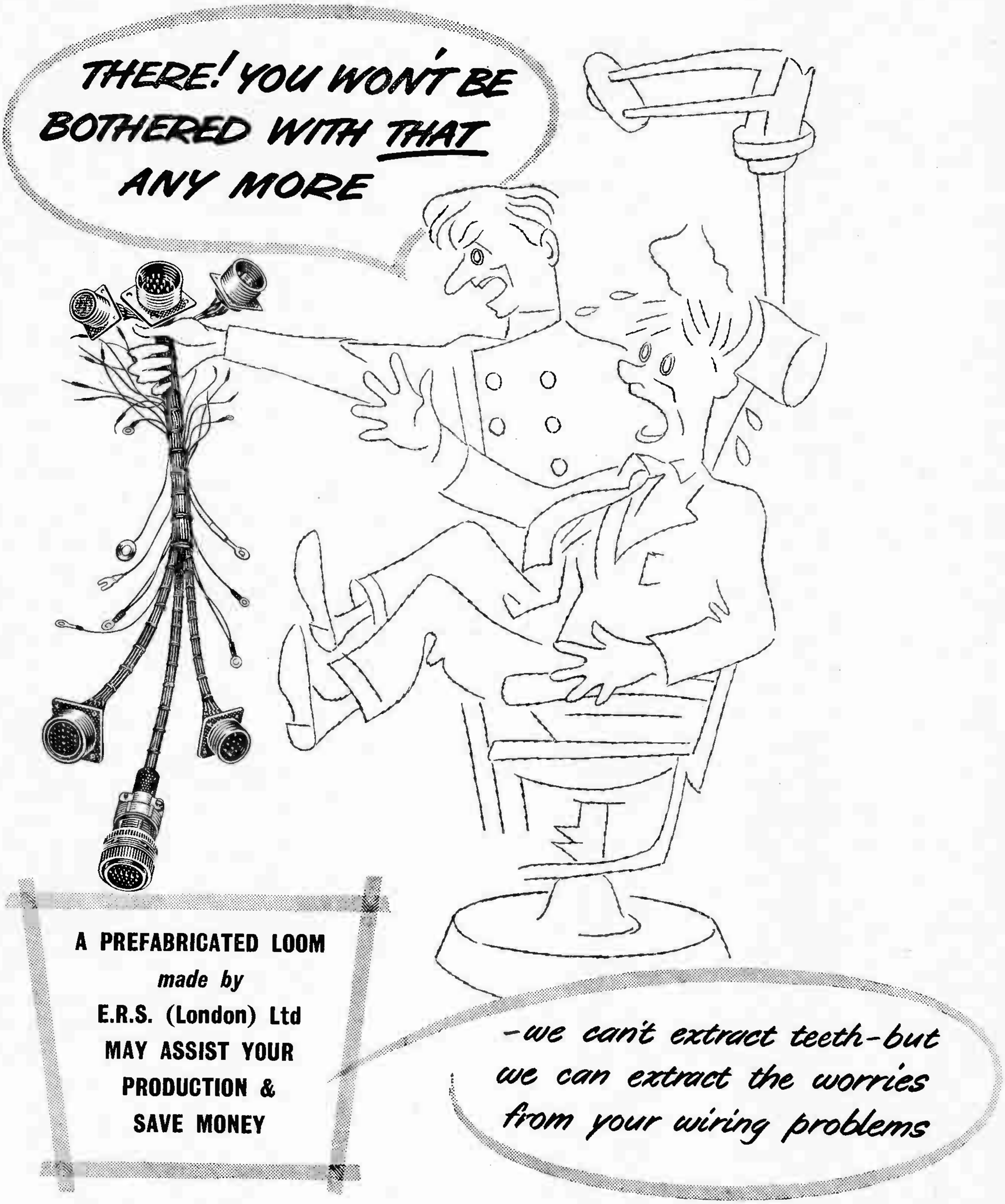
LOW-INERTIA MOTORS

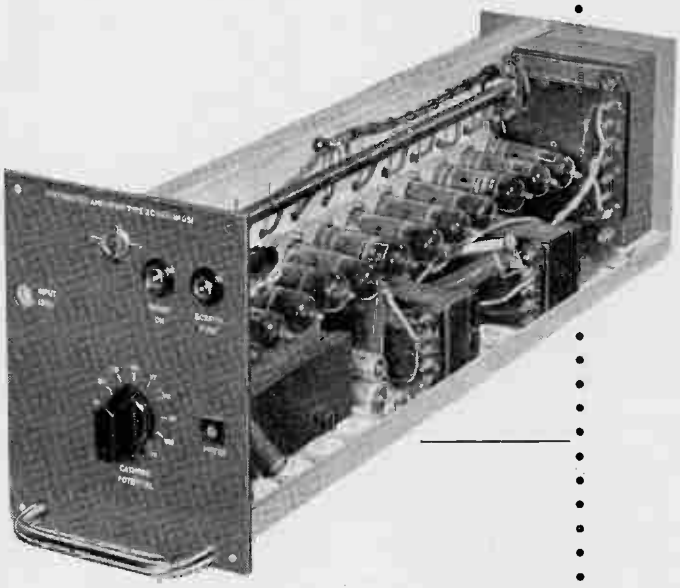
- Linear voltage/speed characteristic
- Starting power: 6 microwatts
- Permanent magnet
- Nom voltages: 1.5, 6, 12, and 24V d.c.

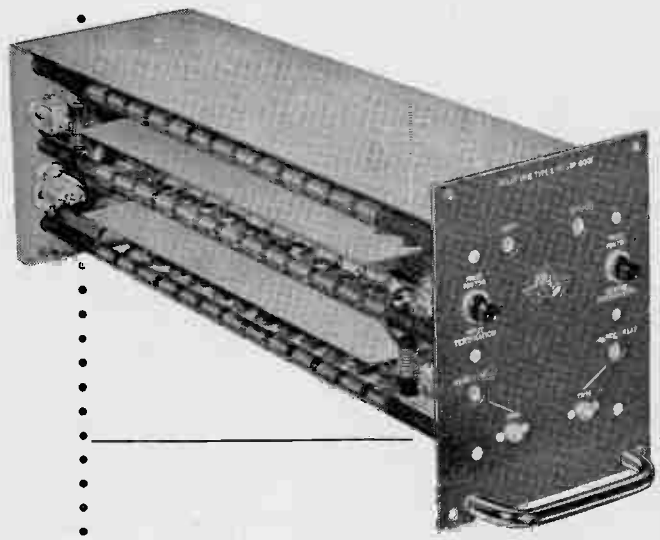
D.C. TACHO GENERATOR

- Linear voltage/speed characteristic
- Compact design for standard fixing
- Synchros size 11, grade 2
- Output voltage: 5.75 per 1000 rpm.

ELECTRO-METHODS LTD. 22-46 CAXTON WAY, STEVENAGE, HERTS. Phone: STEVENAGE 780


THERE! YOU WON'T BE BOTHERED WITH THAT ANY MORE
A PREFABRICATED LOOM made by E.R.S. (London) Ltd MAY ASSIST YOUR PRODUCTION & SAVE MONEY
—we can't extract teeth—but we can extract the worries from your wiring problems





ELECTRONIC & RADIO ENGINEER

incorporating WIRELESS ENGINEER

CONTENTS

VOLUME 34 NUMBER 6 JUNE 1957

Established 1923
Published on the fifth of each month

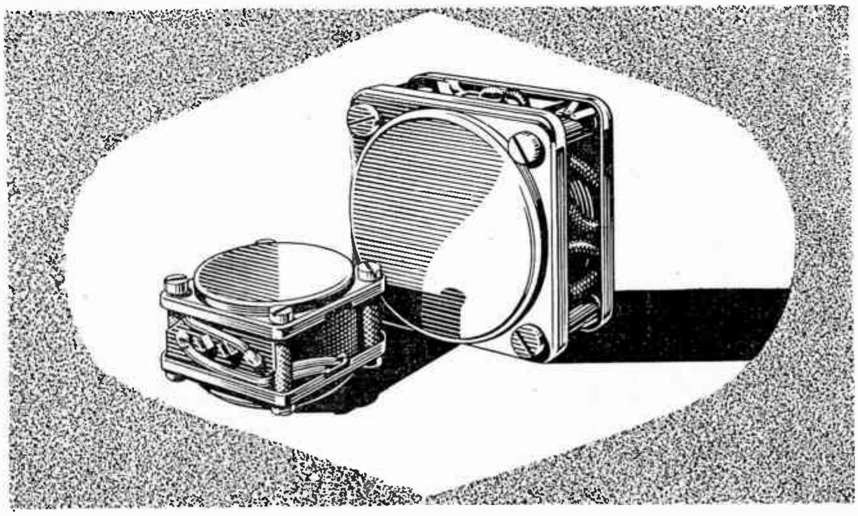
ANNUAL SUBSCRIPTION
(including Annual Index to Abstracts and References)
Home and Overseas £2 9s od
Canada and U.S.A. $7.50

PUBLISHED BY ILIFFE & SONS LTD. DORSET HOUSE STAMFORD STREET LONDON S.E.I
Telephone . Waterloo 3333 (60 lines) *Telegrams . Wirenger, Sedist, London*

BRANCH OFFICES AT BIRMINGHAM MANCHESTER GLASGOW

THESE HIGH Q COILS

are now even easier to install



Designers of communications equipment, will welcome the new mounting and terminating arrangements of the Mullard 25mm and 36mm pot cores.

Unique design features that make installation easier than ever, include positions for tag boards on three sides and a new system of fixing, which eliminates the need for additional mounting plates.

Combining constructional advantages with sound technical performance, these 25mm and 36mm pot cores take full advantage of the low loss of Ferroxcube to produce inductances of up to 30 henries, together with high Q values over a wide frequency range. As an additional service these pot cores can be supplied wound to individual specifications, if required.

Write now for full details of the comprehensive range of Mullard pot cores currently available.

Outstanding features

* Controllable air gap, facilitating inductance adjustment
* Self screening
* Controllable temperature coefficient
* Operation over a wide frequency range
* Ease of winding, and assembly

Mullard

'Ticonal' permanent magnets
Magnadur ceramic magnets
Ferroxcube magnetic cores

MULLARD LTD., COMPONENT DIVISION, MULLARD HOUSE, TORRINGTON PLACE, W.C.1

MC 257A

VOLUME 34 NUMBER 6

ELECTRONIC & RADIO ENGINEER

JUNE 1957 *incorporating WIRELESS ENGINEER*

Colour Television

A MODIFICATION of the N.T.S.C. colour television system, which is claimed to simplify the receiver, is reported in *Télévision* (May 1957, p. 123). Instead of transmitting the two chrominance components simultaneously they are transmitted alternately. The chrominance sub-carrier consequently carries only one modulation instead of two, and a simple diode detector suffices and replaces the usual synchronous detector.

The idea is to transmit blue signals, say, during the first line, red during the second, blue during the third, and so on. A delay line is included in the receiver and is designed to give a delay of precisely one-line period so that, at any instant, one whole line is stored within it. During one line an electronic switch connects to the output of this delay line both the blue gun of the tricolour tube and the luminance-chrominance subtraction circuit, while the input of the delay line is connected to the red gun and the other terminal of the subtraction circuit. During the next line the connections are reversed; that is, the blue gun is connected to the input and the red gun to the output of the delay line.

At an instant, therefore, when the blue gun, say, is being fed directly with the blue signal the red gun is being fed with the red signal of the previous line. At the same time the green gun is being provided with a signal derived by subtracting from the luminance signal the blue signal of the same line and the red signal of the previous line.

The idea behind the scheme is to apply the principle of restricted bandwidth for the chrominance components to the vertical direction of the picture instead of only to the horizontal and thereby simplify the apparatus.

Sufficient details are not given to enable one to make a proper appraisal of the possibilities of the system. *Télévision* reports: "Les diapositifs en couleurs qui étaient utilisés pour la démonstration apparurent sur l'écran avec une excellente netteté et un naturel absolument étonnant dans les couleurs".

It is evident that all three guns are operative simultaneously so that the system should be free from those stroboscopic effects which become evident in normal line-sequential systems. It is a matter for trial whether or not the picture degradation brought about by the fact that two lines are mixed up is important. In this connection, it must be remembered that the demonstration was carried out with the French 819-line system; if the new system has the effect of reducing this to 409 lines it is probably tolerable, but we should not care to drop to 202 lines.

We suspect, therefore, that the method might be inapplicable to British television, but it is one of considerable technical interest and it shows that by no means all engineers are satisfied that the N.T.S.C. system represents finality in colour television.

The Vectorscope

FOR PROVING COLOUR TELEVISION SIGNALS

By N. N. Parker Smith, B.Sc., A.M.I.E.E. and C. J. Matley*

Although the vectorial representation of colours is not in any way restricted to the case of television signals of the N.T.S.C. type, it is this type of signal for which the vectorscope was primarily designed. In an earlier issue of this journal[1], 'Quantum' has already traced the development of the modern colour triangle from Newton's original colour circle, and the significance of the vectorial method of defining colours is clearly shown. The use of vectors is, however, particularly appropriate to the N.T.S.C. type of signal in which the chrominance component is transmitted by means of a sub-carrier modulated both in amplitude and phase. Once the signal has been put into this form, any subsequent distortion will usually be a combination of amplitude and phase errors. Examination of the demodulated signal in vector form presents these errors directly.

The vectorscope, a photograph of which is shown in Fig. 1, has been designed to display the chrominance component of the colour television signal as a pattern of vectors. The use of the instrument for colour work is analogous to that of the normal waveform monitor employed for monitoring black-and-white signals. It does not, however, replace the normal waveform monitor when dealing with colour signals. Both are needed, the vectorscope for the chrominance and the waveform monitor for the luminance signal.

In common with the waveform monitor, the vectorscope gives little qualitative information when a normal programme signal is being transmitted. When used with the appropriate test-signals, however, a quick and accurate check on the overall performance of the whole system is obtained.

Fig. 1. *The vectorscope*

General Description

The display is presented on a cathode-ray tube, signals representing two orthogonal component vectors of the colour vector under observation being fed to the two pairs of plates. The original vector is thus reconstructed on the screen of the cathode-ray tube as the resultant of these two components. The amplitude of the vector, denoting colour saturation, is given by the radial distance of the spot from the centre of the tube and the phase, denoting hue, is given by the angular displacement of the spot from a given reference on the screen.

Modulation of the deflection signals to convert the dots representing the vector tips into radials, a feature adopted in some applications[3], is not used since the position of the vector tips may be determined with greater accuracy from the stationary spot. In addition, the total information content of the display would be somewhat reduced by the confusion of the trace during the transients between the dots.

As already stated, the vectorscope has been designed primarily for use with the N.T.S.C. type of signal. To understand how the instrument operates it is necessary to know the exact form which this signal takes. There are now many excellent accounts available, see reference 2 to quote only one, and we shall give here only those definitions essential to the description of this instrument.

Letting the quantities V'_G, V'_R, V'_B represent the three primary components of the signal, this being the

* *Marconi's Wireless Telegraph Company Ltd.*

form in which it is normally generated by the camera and also that in which it is finally displayed on the receiving screen, then the three transmitted components representing the signal before modulation of the sub-carrier are given by:

$$V'_Y = 0{\cdot}59V'_G + 0{\cdot}30V'_R + 0{\cdot}11V'_B \quad \ldots \quad (1)$$

$$V'_I = -\,0{\cdot}27\,(V'_B - V'_Y) + 0{\cdot}74(V'_R - V'_Y) \quad (2)$$

$$V'_Q = 0{\cdot}41(V'_B - V'_Y) + 0{\cdot}48(V'_R - V'_Y) \quad \ldots \quad (3)$$

where V'_Y represents the luminance component and V'_I and V'_Q together form the chrominance component of the signal. Following the normal convention, the symbol V'_G is used to denote the gamma-corrected form of the original component V_G and similarly for the other components.

The points to note here are that these relationships are so chosen that V'_Y completely specifies the luminance component of the signal and contributes nothing to the chrominance, while the chrominance component V'_C is completely specified by V'_I and V'_Q which in turn contribute nothing to the luminance component. (To avoid possible confusion, it should be added that this statement is strictly true only when considering a linear system; that is, one in which no gamma correction is applied. When using gamma correction the chrominance component does have some effect on the luminance.) For convenience in receiver design, V'_I and V'_Q are taken as two colour difference signals. It will be seen from equations (2) and (3) that they are expressed in terms of two other colour difference signals $V'_B - V'_Y$ and $V'_R - V'_Y$. These two quantities themselves actually formed the two components of the chrominance signal in an earlier version of this system. The two quantities V'_I and V'_Q were later chosen as giving the optimum colour performance for a minimum bandwidth. A further consequence of these relationships is that V'_C vanishes in the absence of any colour information; that is, for whites and greys. This last property results from the fact that the three primary components V'_G, V'_R, V'_B, and hence V'_Y, are all equal to unity when white is being transmitted. The difference signals V'_I, V'_Q, $V'_B - V'_Y$ and $V'_R - V'_Y$ are thus all equal to zero.

Before transmission, the two chrominance components are first combined on a single sub-carrier to form the chrominance signal. This is added to the luminance to form the composite colour signal which may then be transmitted in exactly the same way as is at present used in our regular black-and-white transmissions, that is by direct amplitude modulation of the vision r.f. carrier. The method by which the two chrominance components are combined is known as synchronous modulation. In effect, two components differing in phase by 90° are derived from the unmodulated sub-carrier and each of these components is modulated by one of the chrominance vectors V'_I and V'_Q, a suppressed-carrier system being used. The chrominance signal V'_C is the vector sum of these components, thus

$$V'_C = V'_Q \sin\,(\omega t + 33°) + V'_I \cos\,(\omega t + 33°) \quad (4)$$

where ω represents the sub-carrier frequency. The vector diagram shown in Fig. 2 shows the relationship between the various components in equation (4) and the $V'_B - V'_Y$ axis.

The complete signal may be obtained by adding equations (1) and (4), thus:

$$V_M = V'_Y + V'_Q \sin\,(\omega t + 33°) + V'_I \cos\,(\omega t + 33°) \quad \ldots \quad (5)$$

One further piece of information is required to complete the signal for transmission, although this is not shown in the equations. This is the synchronizing information, the mixed synchronizing pulses together with the colour sub-carrier reference burst.

Having allotted to V'_I and V'_Q two vector directions at 90° the magnitude and direction of the vectors representing all the primary and complementary colours may be calculated. These are shown in Fig. 3.

A vectorscope intended for use with a signal of the N.T.S.C. type must be designed to accept this complete signal. Since, however, the instrument only makes use of the chrominance component, the luminance component, with the exception of the synchronizing information, is rejected.

Circuit Description

A simplified block diagram of the instrument is given in Fig. 4.

The circuit may be divided into three sections:—

Chrominance Channel containing the band-pass amplifier, demodulators and deflection amplifiers.

Synchronizing Circuits containing the synchronizing pulse separator, the clamp pulse generator, and the burst gating-pulse generator.

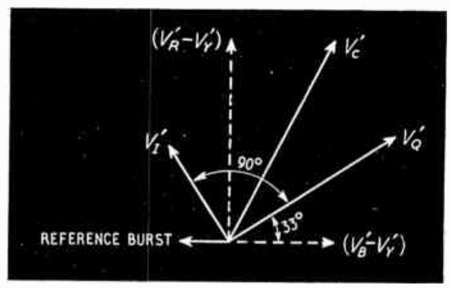


Fig. 2. *Vector diagram showing phase relationships between the various colour-difference signals and the reference burst*

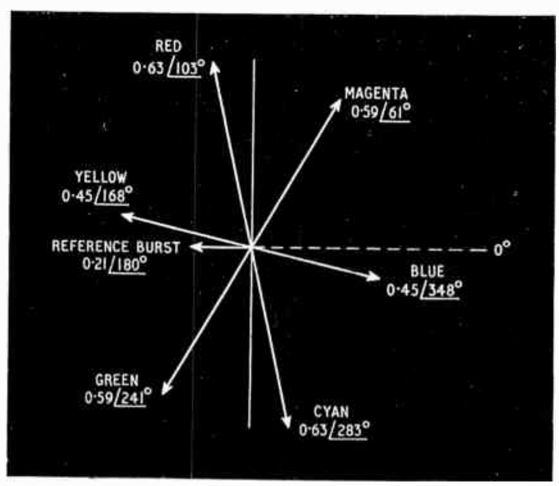


Fig. 3. *Vector diagram showing amplitudes and phase angles for the saturated primary and complementary colours*

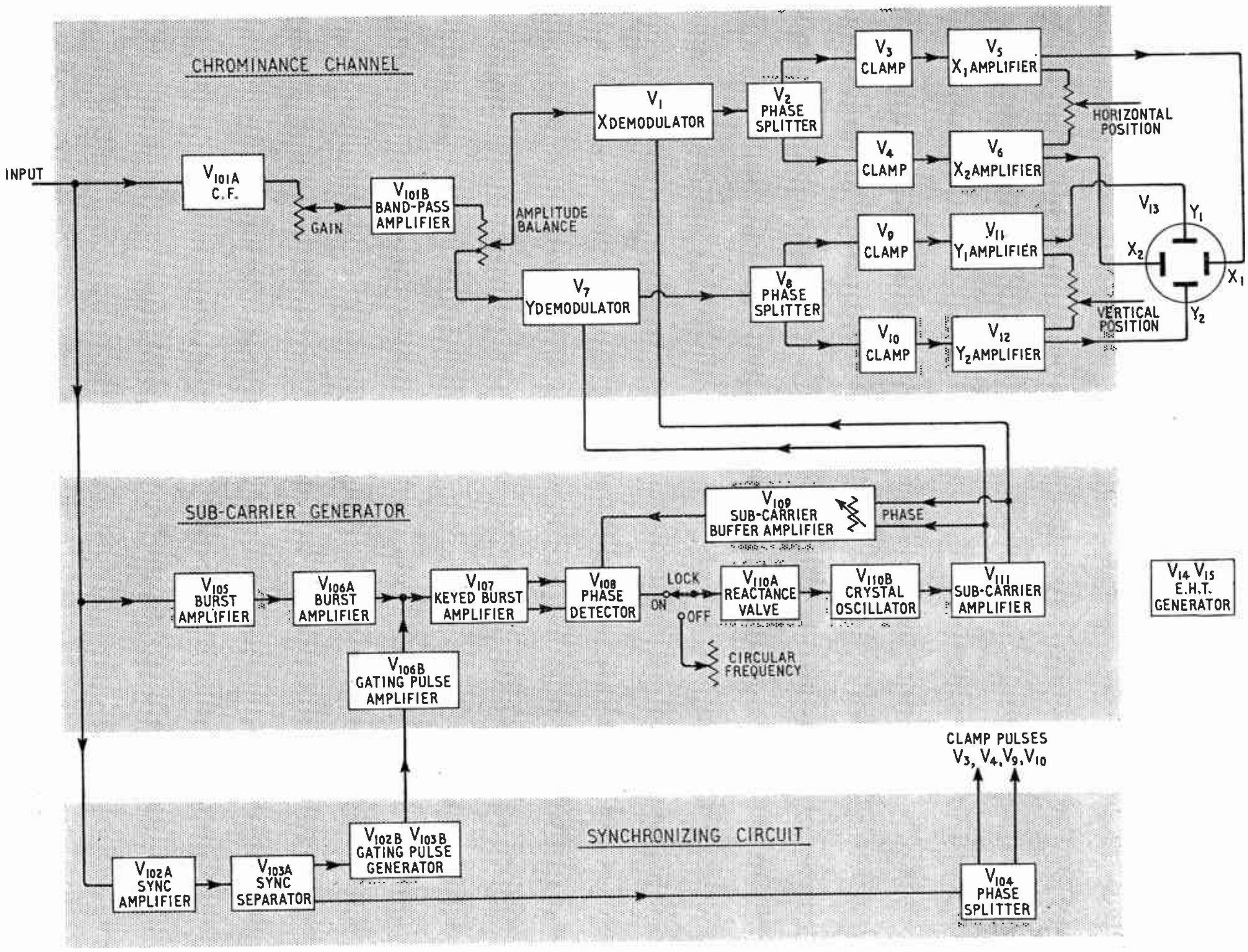


Fig. 4. *Block diagram of vectorscope*, V_1, V_7, 6AS6; V_2, V_8, ECC85; V_3, V_4, V_9, V_{10}, V_{108}, D77; V_5, V_6, V_{11}, V_{12}, V_{14}, 6CL6; V_{13}, S6G; V_{15}, E2004; V_{101}, V_{102}, V_{103}, 6U8; V_{104}, V_{105}, V_{107}, V_{111}, 6AH6; V_{106}, V_{110}, 6AN8; V_{109}, ECC91

Sub-Carrier Generator containing the burst amplifier, the burst-controlled oscillator, and the sub-carrier amplifier.

The inputs to these three sections are in parallel and are fed with an input signal of the form already described.

Synchronizing Circuits

The incoming signal is amplified and inverted in the pentode V_{102A} and the output of this stage is fed to the conventional synchronizing-pulse separator V_{103A}. The negative pulses from this pentode are fed to the phase-splitter V_{104}, also conventional, and the two opposite-polarity outputs from this stage are used for clamping purposes. The two triode sections V_{102B}, V_{103B}, are connected as a monostable pulse generator. This stage is triggered by the separated synchronizing pulses from V_{103A} to give a negative pulse immediately following each synchronizing pulse. The negative pulses from this generator are used to gate out the colour sub-carrier reference burst, the widths of the pulses being adjusted to include the whole burst and to exclude the remainder of the signal.

Sub-Carrier Generator

The incoming signal is again amplified and inverted in the pentode V_{105}, a conventional wideband amplifier. The signal is further amplified with phase inversion in the pentode section V_{106A}. The triode section V_{106B} is fed with the negative gating pulse from the pulse generator V_{102B}, V_{103B}. The two signals are mixed in the anode circuits of the two stages, V_{106A} and V_{106B}, with the result that the now positive gating pulse is added to the reference burst and raises it above the normal signal level. This combined signal is fed to the grid of the pentode V_{107}, the cathode of this stage being held at a potential which permits the valve to conduct only during the burst period. A transformer with a centre-tapped secondary in the anode circuit of V_{107} provides push-pull outputs of the colour sub-carrier reference burst to the diode phase detector V_{108}.

The triode section, V_{110B}, is connected as a conventional crystal oscillator operating at the sub-carrier frequency. The frequency of this oscillator is controlled by the reactance valve V_{110A} which normally derives its control voltage from the phase-detector V_{108}. The output from V_{110} is amplified in V_{111} and a quadrature transformer in the anode of this stage provides two outputs at sub-carrier frequency and differing in phase by 90°. These two signals are fed directly to the synchronous demodulators, and to the buffer amplifier V_{109} which delivers one phase-adjustable signal to the phase-detector V_{108}. A simplified circuit of these stages is shown in Fig. 5.

The primary function of V_{109} is to isolate the sub-carrier reference signals from the phase detector and so prevent modulation of the reference signals by the synchronizing burst. Any such effect would modify the demodulator outputs and, consequently, the vector representing the reference burst would be incorrectly displayed. This particular difficulty is not encountered in the case of a colour receiver since the burst itself is not actually shown. The phase control in the anode circuit of V_{109} enables the final display to be aligned with the graticule. A total range of 60° is obtained without change in amplitude. This feature allows the full locking or pull-in range to be maintained at any setting of the phase control.

Chrominance Channel

The input to the chrominance amplifier is fed to the cathode follower V_{101A} in the cathode circuit of which is a gain control. The following stage V_{101B}, a conventional band-pass amplifier, is designed to restrict the signal passed on to the band of frequencies which contains the chrominance information. A bandwidth of ±1·3 Mc/s centred on the sub-carrier frequency of 2·66 Mc/s has been adopted in the case of the anglicized version of the N.T.S.C. system. The filtered chrominance component, as represented by equation (4), is fed to the two synchronous demodulators V_1 and V_7, an amplitude balance control being provided to equalize the gains of the two channels. The demodulators are also fed with the quadrature outputs from V_{111}. A simplified diagram showing one demodulator is given in Fig. 6. The chrominance component, V'_C is fed to the grid while a reference signal, $2 \sin (\omega t + 33°)$ for the one demodulator and $2 \cos (\omega t + 33°)$ for the other, is fed to the suppressor. (These phases for the reference signals have been chosen to keep equations (6) and (7) as simple as possible. In principle any phases may be chosen and those actually used are discussed below.)

Taking the product term at the anode we get in the first case:

$$2K \sin (\omega t + 33°) \{ V'_Q \sin (\omega t + 33°) + V'_I \cos (\omega t + 33°) \} = KV'_Q \{ 1 - \cos 2(\omega t + 33°) \} + KV'_I \sin 2(\omega t + 33°) \quad (6)$$

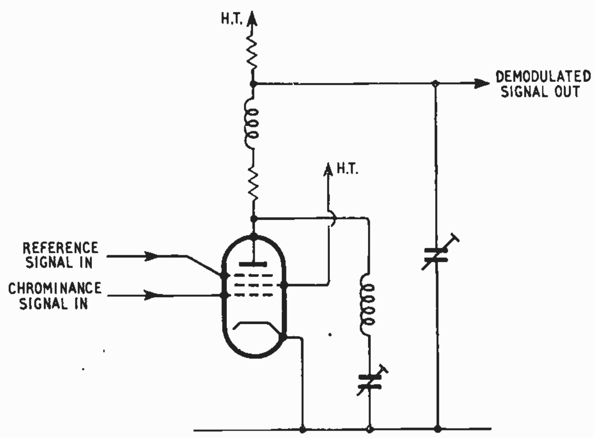


Fig. 6. *Basic circuit of synchronous demodulator*

where K is a constant; and in the second case we get:

$$2K \cos (\omega t + 33°) \{ V'_Q \sin (\omega t + 33°) + V'_I \cos (\omega t + 33°) \} = KV'_Q \sin 2(\omega t + 33°) + KV'_I \{ 1 + \cos 2(\omega t + 33°) \} \quad (7)$$

The signal at the anode of each demodulator is given by the terms on the right-hand side of the appropriate equation, (6) or (7), in addition to which there is in each case a component at the fundamental sub-carrier frequency introduced by the standing current in the stage and not therefore shown in the equations. It will be noted however that a low-pass filter is inserted immediately after this point so that all the fundamental and double-frequency terms are removed. The outputs of the two stages thus become KV'_Q and KV'_I respectively and it will be seen that reference signals of the two phases adopted in the above illustration will recover the original chrominance-component vectors, V'_I and V'_Q, as against any other colour-difference signals which would have resulted if different reference signals had been used. Because the eye is least sensitive to detail in colours lying along the Q axis and most sensitive to detail in colours lying along the I axis, the maximum use is made of the available bandwidth by using these axes in the encoding process, the I signal being allotted a greater bandwidth than the Q. In actual fact, therefore, demodulation along the I and Q axes will recover

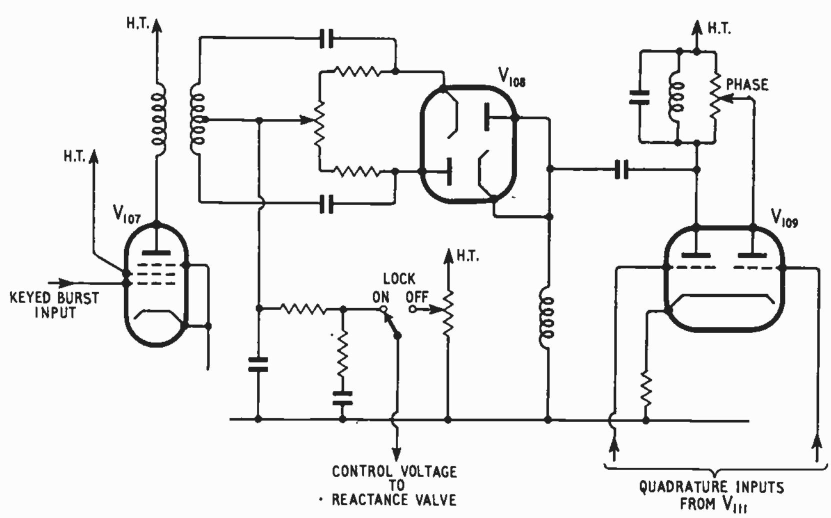


Fig. 5. *Locking circuit showing method of phase control*

the maximum degree of information from the signal, and a colour receiver designed to make the optimum use of the chrominance information must employ I and Q demodulators. With the vectorscope, however, we are not concerned with the portrayal of fine detail, and it is immaterial which axes are adopted for the demodulators.

The conventional orientation of the vector display is most easily obtained by adopting the original $B-Y$ and $R-Y$ axes and these will result by using reference signals directly in phase and in quadrature with the burst. The manipulation of equations (6) and (7) is more tedious in this case but the two resulting expressions reduce to V'_{B-Y} and V'_{R-Y}.

The remainder of the chrominance channel comprises two push-pull deflection amplifiers. The two outputs from the demodulators are fed to two phase-splitter stages V_2 and V_8. Each stage employs a double triode with the two sections connected in cascade, the drive for the second half being derived from the junction of two series resistors connected between the anodes in the conventional way. By this method, balanced outputs are obtained which are substantially independent of valve characteristics. The two pairs of opposite-polarity outputs are taken from the anodes of these stages.

The signals are next clamped to ensure that all vectors start from the origin. Four double diodes, V_3, V_4, V_9, V_{10}, are used for this purpose, the switching pulses being provided from V_{101} as already described. Two push-pull amplifiers V_5, V_6, and V_{11}, V_{12} form the final amplifiers, their outputs being d.c. connected to the plates of the display tube. A further stage of filtering is included in each plate connection in order to increase the attenuation at the sub-carrier frequency. The less sensitive X plates are fed with the $B-Y$ signal the axis of which lies nearer to that of the lower-definition Q signal. This channel delivers a peak-to-peak output of 300 V and is flat to 600 kc/s. The $R-Y$ channel supplies the Y plates and delivers an output of 250 V peak to peak with a 1-Mc/s bandwidth. The overall linearity distortion between the demodulators and the plates is less than 1%.

Controls

Apart from the normal controls for Brightness, Focus, Astigmatism, etc., the following operating controls are provided:

Horizontal and Vertical Position: These controls are provided to centralize the spot, in effect they vary the d.c. levels at which the signals are clamped.

Amplitude Balance: This control enables the gains of the two signal channels to be equalized. Use is made of the Lock ON/OFF switch when making this balance.

Lock ON/OFF: Operation of this switch removes the output of the phase-detector from the reactance valve. The sub-carrier oscillator then runs asynchronously and any display on the tube is allowed to rotate. A normally stationary pattern of dots thus becomes a series of concentric circles as shown in Fig. 11. Any misadjustment of the Amplitude Balance Control distorts these circles.

Phase: This control is used to adjust the phase of the display pattern with respect to the graticule. The vector representing the reference burst is normally phased to lie on the burst axis. This control varies the phases of the two reference signals to the demodulators.

Gain: This control is used to give the correct deflection with the standard level of input.

Circular Frequency: This control adjusts the frequency of the sub-carrier oscillator when in the unlocked condition. It is provided to ensure that a convenient rate of drift can always be obtained.

In addition, a preset control is provided on the quadrature transformer which supplies the two reference signals for the demodulators. This adjustment provides means for setting these outputs to be 90° apart in phase. Failure of these two signals to be in quadrature is apparent as distortion of the circles obtained when running in the unlocked condition.

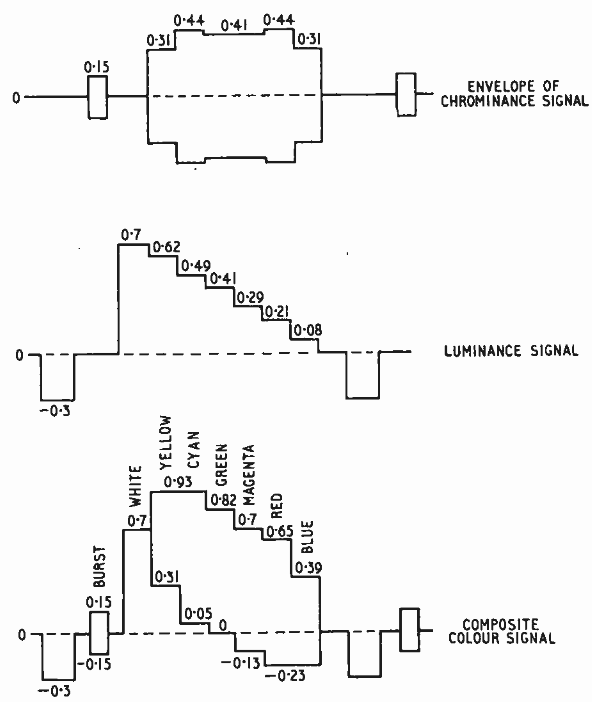
While amplitude unbalance will cause the circles to become ellipses with vertical and horizontal axes, a phase error in the quadrature setting will produce ellipses with inclined axes.

Performance and Features

It will be seen that no additional equipment is required for setting up this instrument and that the methods employed are effectively foolproof. When correctly set the measurement accuracy is $\pm 2°$ in phase and $\pm 2\%$ in amplitude.

An edge-illuminated graticule showing the correct positions for the vector tips corresponding to the colour-bar test pattern is provided. This graticule is engraved with outer boxes representing positional tolerances of $\pm 10°$ and $\pm 20\%$, while closer tolerance boxes inside these represent $\pm 5°$ and $\pm 10\%$. The burst, I and Q axes are also shown.

Fig. 7. *Colour bar test waveform. Composite signal: 100% saturation*



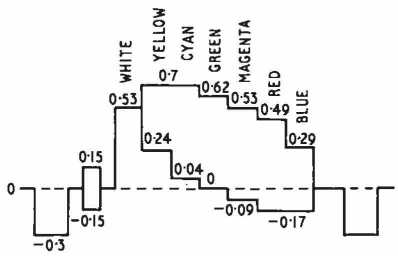


Fig. 8. *Colour bar test waveform. Composite signal: 75% saturation*

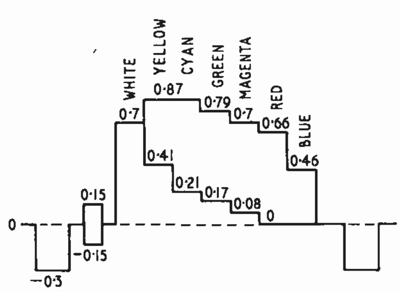


Fig. 9. *Colour bar test waveform. Composite signal:* 100% *saturation;* 75% *normal amplitude*

A circular scale, calibrated in degrees, surrounds the 6-in. c.r.t. screen and a rotatable cursor with four scales facilitates the direct measurement of any vector in a 0·7-V or 1-V standard vision signal at either 100% or 75% saturation.

To enable the instrument to be used at different sub-carrier frequencies, those parts of the circuit involving tuned stages or which have component values dependent upon the frequency in use, are all built on one plug-in assembly. Changing between standards may thus be effected in a relatively short time. Referring to Fig. 4, valves V_{101} to V_{111}, together with their associated components, are mounted on this removable chassis.

The unit is supplied from a standard power unit and draws 120 mA at 360 V unregulated, and 220 mA at 250 V regulated. The unit shown in the photograph also provides switching facilities enabling any of several signals to be viewed at will.

Although the vectorscope is indispensable in the colour-television laboratory or in any place where equipment designed to handle a colour signal is being developed, it is probably as a transmission monitor that this instrument will find its greatest appeal. When used in conjunction with the colour-bar test signal, an immediate and complete measure of performance is obtained. Any combination of amplitude and phase distortion in the outgoing signal is at once revealed.

Colour Bar Test Waveform

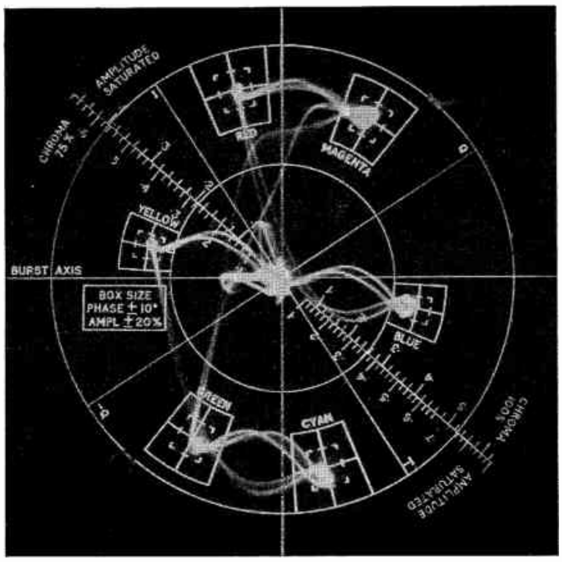
This test signal is electronically generated and produces a pattern of vertical bars when viewed on a picture monitor. In all there are six colour bars, the three primaries green, red, and blue, and the three complementaries yellow, cyan, and magenta. A white bar and a black bar are also included. This pattern may be produced by substituting the *R*, *G*, *B* outputs from a colour-bar generator for the normal camera outputs at the input to the colourplexer or encoding equipment. Alternatively, where complete encoding equipment is not available, a coded colour-bar signal can be directly generated.

The colour saturation of the six bars may be varied to suit the type of test. The waveform in Fig. 7 shows the composite colour-bar signal at full saturation. The two components, luminance and chrominance, are also shown separately. The colour-television system is actually capable of reproducing more highly saturated colours than are commonly found, or are even realizable, in practice. It is interesting to note that regular monitoring of the current series of B.B.C. tests rarely shows a degree of saturation exceeding 50%, either from live scenes or films. A typical slide is shown in Fig. 13. To design every piece of equipment to handle a fully-saturated colour-bar signal is not therefore necessary. In Fig. 8 is shown the waveform corresponding to 75% saturation. In Fig. 9 is shown the form of 'desaturated' test signal employed in America. In this case the saturation is actually maintained at 100% but the amplitude of the whole signal (with the exception of the synchronizing information) is reduced to 75%. It is of interest to note that the use of a 75% saturated signal on a system employing positive modulation effectively eliminates any excursion of the picture signal into the non-linear region of the transmitter. The same is true when the 75% amplitude waveform of Fig. 9 is used on a system employing negative modulation.

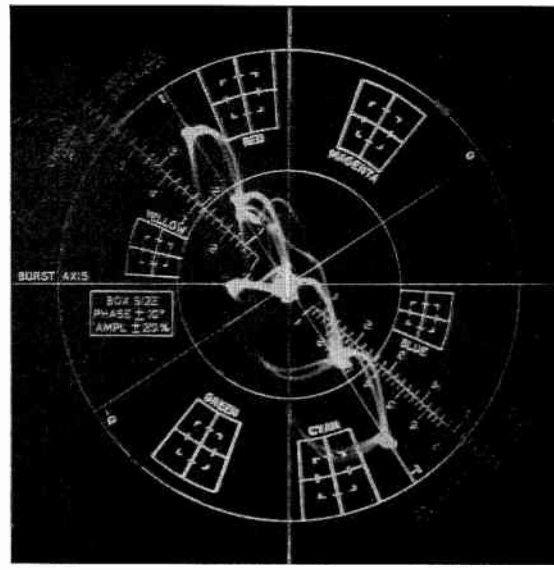
In Fig. 10 is shown a series of photographs taken directly from the vectorscope screen when a 100% saturated colour-bar test signal is being displayed. Referring to Fig. 10(a), the tips of the six colour vectors are indicated by the dots lying within their respective boxes. The dot in the centre of the screen represents the black and white bars and also the synchronizing-pulse period. The remaining dot, lying on the horizontal axis to the left of the centre, represents the reference burst. In Fig. 10(b) the *Q* channel was switched off in the colourplexer, while in Fig. 10(c) the *I* channel was switched off. In either case, the chrominance signal is restricted to a single phase and the resulting pattern is of the form shown, all the dots lying along the axis of the channel in use. The last two displays provide an accurate means of assessing phase-amplitude distortion; that is, variation in phase shift with the luminance level.

The transients between the various bars are shown by the faint traces connecting the dots. These transients appear in duplicate and this is due to the sub-carrier interlace system whereby the sub-carrier frequency is related to the scanning frequency in such a way that the sub-carrier is 180° phase removed on alternate frames or pictures in order to reduce the visibility of the sub-carrier dot pattern on the receiver. The combined luminance plus chrominance transient is therefore different on alternate frames.

In examining these patterns it should also be remembered that the vectorscope displays signals at all frequencies which lie within the acceptance band required to obtain the complete chrominance signal. Any luminance transients with components within this

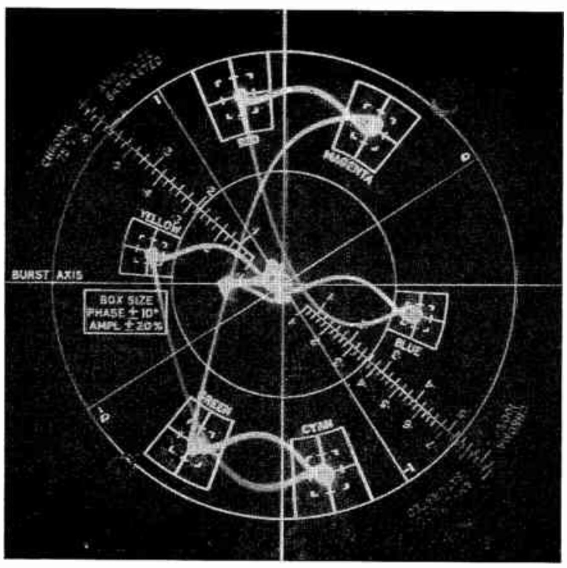


(a)

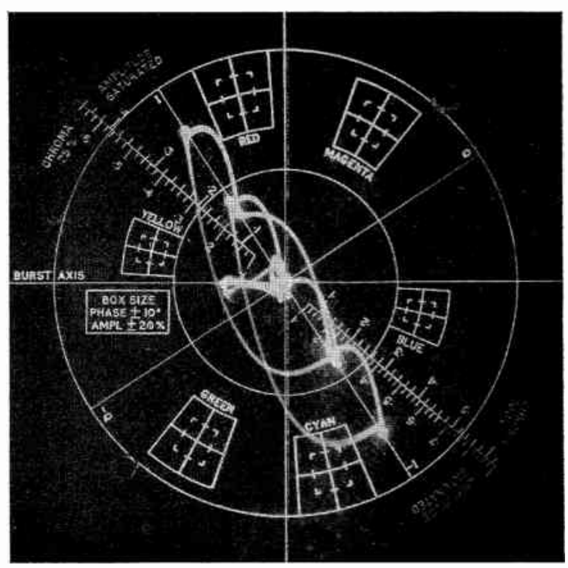


(b)

FIG. 10. *A SERIES OF PHOTOGRAPHS ILLUSTRATING THE VARIOUS*



(e)

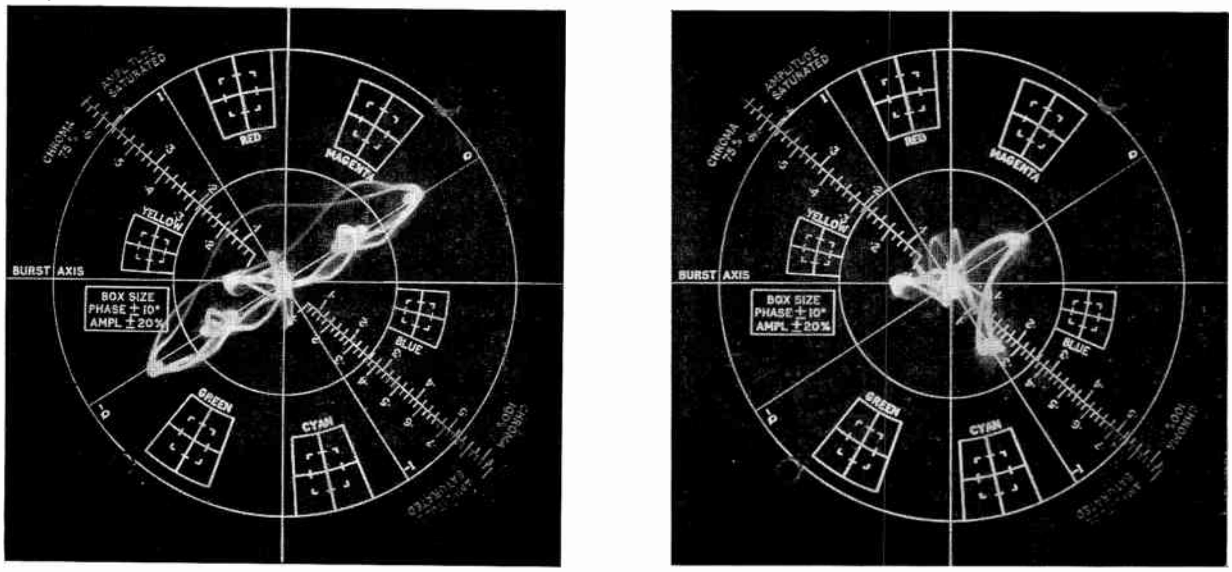


(f)

band will also be displayed. As an example of this, a short loop, such as that starting and finishing at the centre of the screen on these photographs, may well be due to the rising or falling edge of the synchronizing pulse.

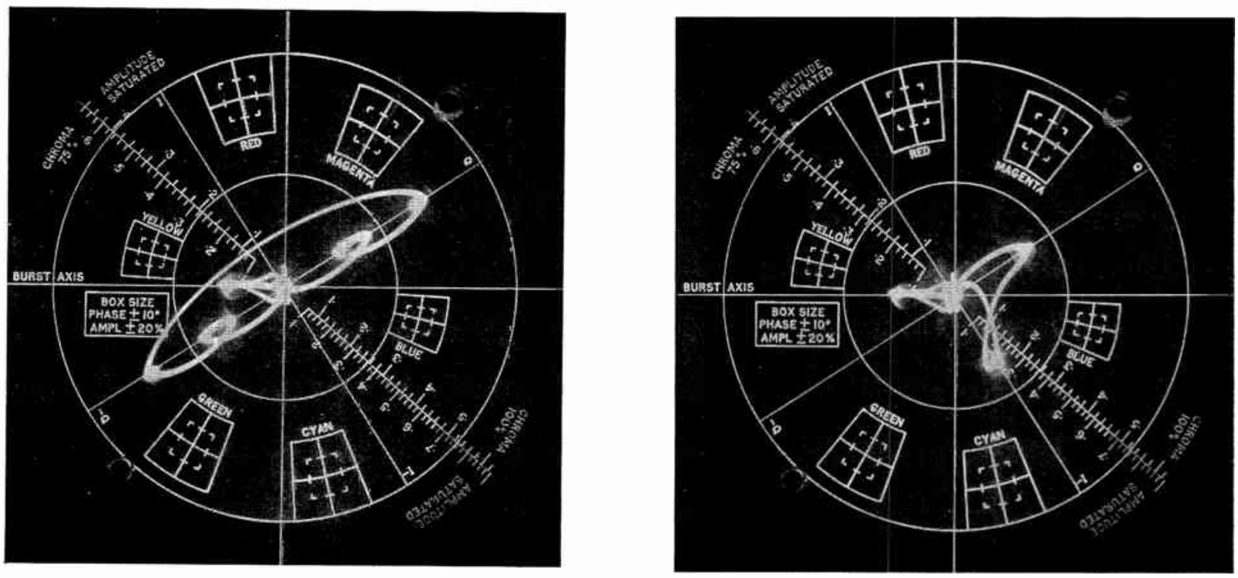
On looking at the photographs, one might also ask why this particular order of colour bars had been chosen when a much simpler pattern would have resulted if the bars had been taken in logical order round the vector diagram (Fig. 3). As will be seen from Fig. 7, the bars are actually in descending order of luminance, a feature which leads to a logical presentation when viewed on a black-and-white receiver. This sequence also imposes a more stringent test on the system calling in one case, green to magenta, for 180° change of phase on the transition. With the bars in phase order, the transitions all involve about the same phase change of approximately 60°, and the resulting display resembles a polygon.

Figs. 10(e), (f), and (g), are repeat photographs of the first three displays taken with the luminance component switched off in the colourplexer. The possibility of introducing phase-amplitude distortion between the synchronous modulators and the vectorscope is now removed and the accuracy of the encoding system can therefore be independently checked. It will also be seen that the doubling of the trace during the transients has been eliminated, a natural consequence of eliminating



(c) (d)

EFFECTS DESCRIBED IN THE TEXT AS SEEN ON THE VECTORSCOPE



(g) (h)

the luminance transients. It should be added that for normal use the brightness may be adjusted to render the transients invisible.

I and Q Bars

A simpler test signal to generate is one which merely consists of two bursts of sub-carrier corresponding in phase to the I and Q axes on the vector diagram of Fig. 3. Black and white bars may easily be added if desired. Photographs of the resulting four-bar pattern with and without luminance are shown in Figs. 10(d) and 10(h). The signal may be generated by feeding separate exciting pulses to the I and Q modulators in the colourplexer, and the resulting vector display will then check the phases of these axes relative to each other and to the reference burst. This signal is of little value for checking phase-amplitude performance in intervening units, so that there is little point in generating it except in the way suggested. If transmitted, however, this signal provides a valuable means of checking the demodulation axes in receivers.

A combined test signal may be derived by mixing the colour-bar waveform with the I and Q signals so that they appear in the upper and lower halves of the picture respectively. The display obtained is shown in Fig. 12.

Other Uses

Apart from its use with the above test waveforms both

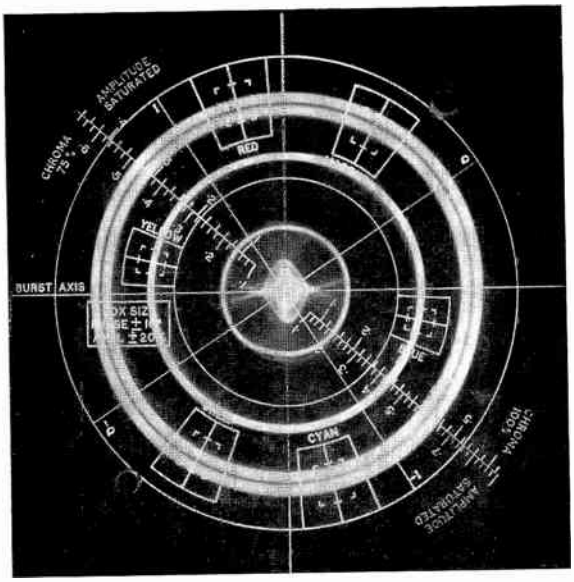


Fig. 11. *Setting-up display obtained by unlocking the colour bar pattern. The truth of the circles indicates that the instrument is properly adjusted*

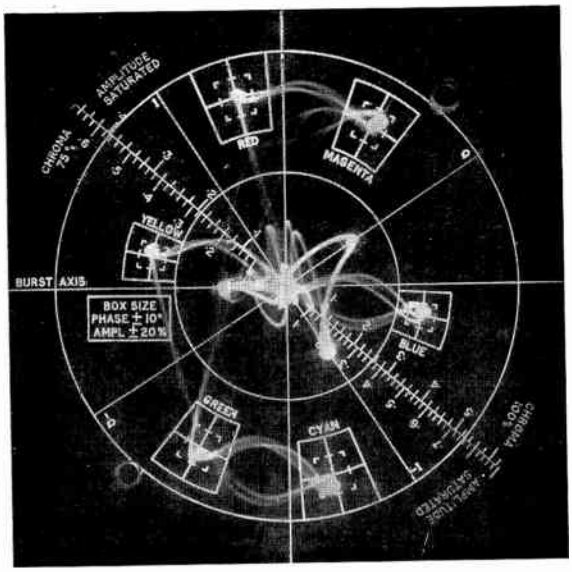


Fig. 12. *A combined test signal comprising colour bars in the top half of the picture and I and Q signals in the bottom half, or vice versa*

of which are peculiar to colour television, valuable information may be obtained when the instrument is used in conjunction with the normal test waveforms in common use on black-and-white systems. The stepped sawtooth or staircase waveform, upon which a constant-amplitude constant-phase sine wave (in this case at sub-carrier frequency) has been superimposed, is a good example.

In addition to its use purely as a piece of test equipment, the vectorscope may be used for the qualitative appraisal of programme material. For example, the results obtained by using various paints, dyes, light-filters, etc., may be recorded and compared with those obtained by different observers or at different times. Film quality may also be assessed and the instrument provides a valuable means of accurately matching a number of colour-television cameras.

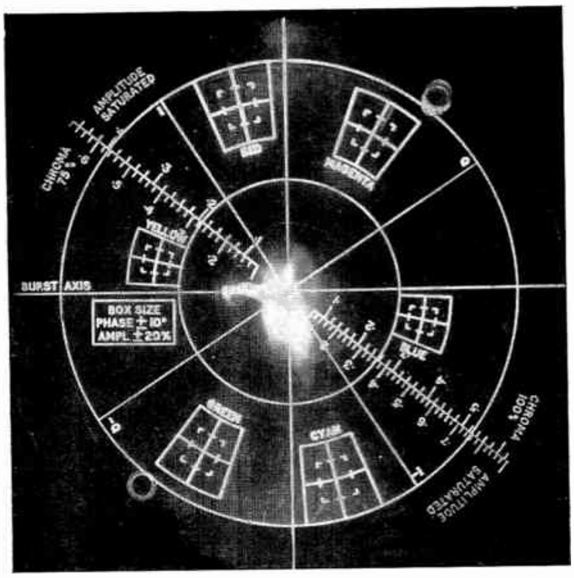


Fig. 13. *The vector display obtained using an average colour slide. This slide demonstrates the low degree of colour saturation normally found*

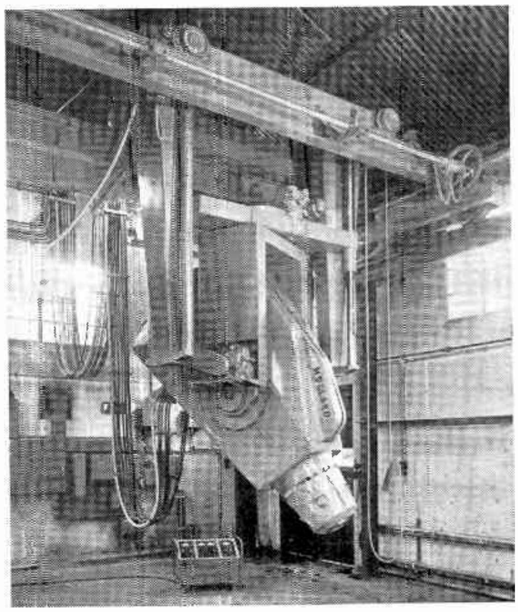
A number of other uses have also been suggested for this instrument. The references given below discuss various applications, in particular to f.m. systems and to direction-finding.[3]

The authors desire to thank the Engineer-in-Chief, Marconi's Wireless Telegraph Co. Ltd., for permission to publish this article.

REFERENCES

[1] *Electronic & Radio Engineer*, February 1957.
[2] C. J. Hirsch, "Principles of N.T.S.C. Colour Television", *Proc. Instn elect. Engrs*, February 1956.
[3] K. Schlesinger, "Phase Measurements for Colour Television and F.M.", *Electronics*, February 1955.

LINEAR ACCELERATOR



The Mullard 5-MeV linear accelerator is designed for industrial radiography. It is mounted on rails so that it can be traversed to any part of the room. The control unit is visible below the accelerator

Grid-Circuit Distortion

By E. Watkinson*

SUMMARY. *Conventional analyses of valve performance have established the dichotomy of negative control-grid operation without grid current and positive control-grid operation with grid current. This convention is satisfactory for most valve applications, but requires modification for some low-bias operating conditions.*

Positive control-grid currents are known to approach zero exponentially with increasing negative bias[1,2] *and valves are frequently operated under conditions which lead to control-grid currents between* 10^{-6} *and* 10^{-9} *A. The effects of currents of this order, modulated by a signal and flowing in an impedance in the control-grid circuit, are analysed.*

It is shown that operating conditions recommended by many valve manufacturers may lead to grid-circuit distortion at least comparable with that produced in the anode circuit of a valve. Conditions are recommended to reduce this distortion to negligible proportions.

In an investigation of the effects of small values of control-grid current, both the slope of the current-voltage characteristic and the magnitude of the current are important. Many factors affect these characteristics, but the investigation shows that none of them leads to any appreciable divergence from the slope of the classical retarding-field diode characteristic. The magnitude of the grid current, however, is affected.

When, in a multigrid valve, voltages are applied only to the control-grid–cathode system, the valve behaves as a conventional diode and current flows to the grid under saturated, space-charge-limited or retarding-field conditions according to the magnitude and polarity of the applied voltage[3,4]. With a control-grid voltage sufficiently negative to bring about retarding-field conditions the grid current is approximately *

$$I_R = I_s \exp.\ (Ee/kT)\ \text{amp.} \qquad (1)$$

where I_s = total emission from cathode at temperature T, amp.
e = electronic charge (coulomb).
E = applied potential (including contact potential difference),
k = Boltzmann's constant (joules per degree Kelvin).
T = cathode temperature (degrees Kelvin).

Taking the logarithm of both sides and differentiating:

$$\frac{d(\log_\epsilon I_R)}{dE} = \frac{e}{kT} \qquad (2)$$

$$\text{Since } \frac{e}{k} = 11{,}606 \text{ degrees/volt}$$

$$\frac{d(\log_\epsilon I_R)}{dE} = \frac{11{,}606}{T} \qquad (3)$$

i.e., the slope of the grid characteristic is inversely proportional to the cathode temperature, T.

Thus the retarding-field diode (control-grid) current in a valve having a cathode temperature of 1,161°K decreases to $1/\epsilon$ (i.e., 0·368) of its original value for each additional 0·1 volt of negative bias applied.

* *Amalgamated Wireless Valve Co, Pty, Ltd., Australia*

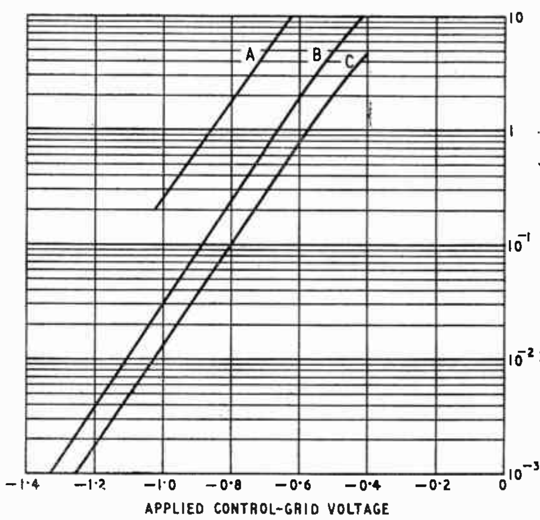
*Equ. (1) applies strictly to infinite parallel-plane electrodes. Schottky[5] has shown that the retarding-field current is slightly modified for cylindrical electrodes

That the effective cathode temperature of typical modern valves is in fact approximately 1,161°K is demonstrated in Fig. 1, the control-grid characteristic of a 6AU6 7-pin miniature r.f. and a.f. pentode. Curve A is the diode curve (grids 2 and 3 and anode earthed) with 6·3 volts applied to the heater, and it will be noted that the grid current increases 2·7 times for each 0·1 volt reduction of negative bias.

Grid Characteristic of Multi-Electrode Valves

Fig. 1 also shows, in curves B and C, the control-grid characteristic of the same 6AU6 valve with 50 and 100 volts positive applied to grid 2 and to the anode, with grid 3 earthed. The tendency towards non-linearity at currents approaching 10 μA is due to the transition from retarding-field to space-charge-limited conditions. Curves A, B and C show that by modifying the electrostatic field between control grid and cathode, the grid 2 plus anode potential has reduced the control-grid

Fig. 1. *Grid characteristics of 6AU6 at 6·3-V heater voltage. Anode and screen voltages zero for curve A, 50 volts for curve B and 100 volts for curve C*



current. The slope of the linear section of the characteristic, however, is virtually unchanged.

This effect can be expressed:

$$I_R = F\, I_s \exp\,(Ee/kT) \text{ amp.} \quad \ldots \quad (4)$$

where F = a factor, usually less than unity, dependent upon the voltages applied to electrodes other than the control grid in a multi-electrode valve.

In pentode applications in which the screen voltage has no a.c. component, investigation shows that fluctuations in the anode voltage of the 6AU6 or other pentode a.f. amplifiers, at least over a linear excursion of the anode characteristic, do not significantly affect the control-grid characteristic.

In triode applications, however, the slope of the grid characteristic is increased by the variation in anode

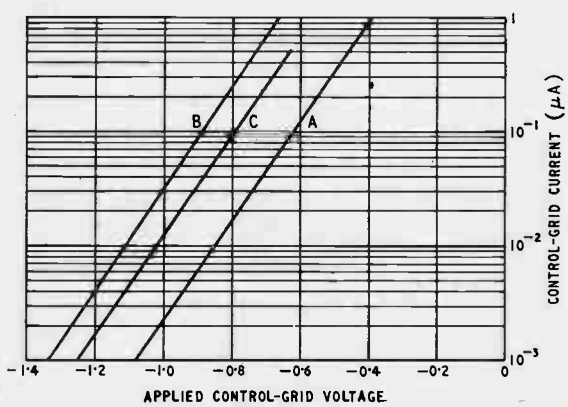


Fig. 2. *Control-grid characteristics of triode-connected valves with 6·3-V heater and 50-V anode voltages. Curve A is for a 6SJ7GT, curve B for a 6AU6 and curve C for a 6BQ7A*

voltage brought about by the application of a signal to the control-grid. Nevertheless, the increase in slope is slight and does not cause a significant departure from that of the original diode characteristic.

Curves B and C of Fig. 1 were obtained by the method described in Ref. 7. Using the circuit of Fig. 5(a) of this reference, grid characteristics can readily be plotted to at least 10^{-9} amp. without special equipment. (It is stated in the reference that the method is satisfactory for currents greater than 10^{-12} amp.).

Grid-Cathode Spacing

An investigation of valves covering the range of differences in spacing between cathode and control grid that is likely to be met in modern a.f. amplifiers shows that this factor has a negligible effect on the slope of the characteristic.

This is demonstrated in Fig. 2, in which curve A is the control-grid characteristic of a 6SJ7GT with spacing between adjacent surfaces of grid and cathode of 0·015 inch, curve B of a 6AU6 with spacing of 0·008 inch and curve C of a 6BQ7A with 0·002 inch. The valves were chosen at random, the pentodes were triode-connected and in each case the characteristics were plotted with heater and anode voltages of 6·3 and 50 volts respectively.

The slope of each grid characteristic closely approximates that of an ideal planar diode with cathode temperature of 1,161°K and in spite of the difference in grid–cathode spacing the magnitudes of the grid currents differ no more than do those of different valves of the same type.

Input Impedance

An interesting aspect of the constancy of slope of the grid characteristic of modern a.c. operated valve types is the fact that the approximate input impedance of any valve of this type biased into the retarding-field region of its grid characteristic can be readily approximated from a knowledge of the magnitude of its grid current.

$$\text{Since } I_R = I_s \exp.\,(Ee/kT) \text{ amp.}$$

$$\frac{dI_R}{dE} = \frac{e}{kT} I_s \exp.\,(Ee/kT) \text{ amp/volt} \qquad (5)$$

Thus, since $e/kT = 10$ approximately, valve input resistance

$$R_i = \frac{1}{10\, I_s \exp.\,(Ee/kT)} \text{ ohms} \ldots \qquad (6)$$

i.e., $R_i = 1/(10\, I_R)$ ohms

or, in words, the small-signal valve input resistance in meghoms is the reciprocal of ten times the grid current in microamps. Thus, if an input impedance only as low as 10 megohms is required, bias must be sufficient to reduce retarding-field grid current to not more than 10^{-2} microamp.

Experimental verification of this statement is given in Fig. 3 in which control-grid current and measured control-grid impedance of a 6AU6 valve with a heater voltage of 6·3V and triode anode voltage of 50V are plotted against control-grid voltage. Grid circuit impedance follows the above rule within the limits of experimental error.

Graphical Representation of Distortion

In many a.f. amplifier applications of valves the signal is applied to the grid through a series impedance; for example, an impedance due to the diode load in the case of the first a.f. amplifier in a radio receiver or due to the impedance of a previous resistance-coupled stage in a conventional amplifier.

The flow of grid current, modulated by signal voltages, in such an impedance results in distortion of the signal applied to the grid of the valve. A graphical construction to demonstrate this is shown in Fig. 4.

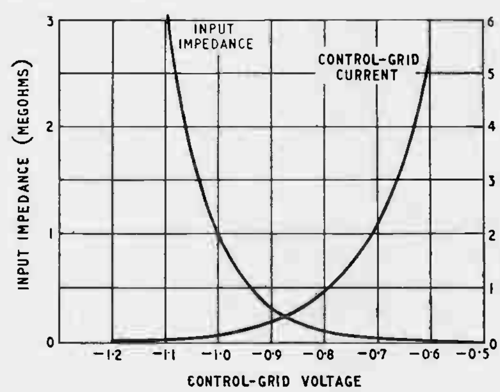


Fig. 3. *Measured input impedance and control-grid current of 6AU6 valve plotted against control-grid voltage*

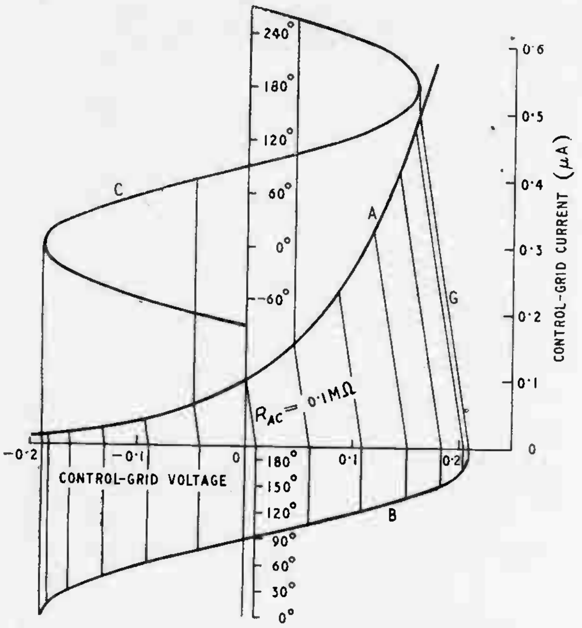


Fig. 4. *Graphical illustration of the generation of distortion in the control-grid circuit of a valve drawing* $0 \cdot 1\ \mu A$ *of standing control-grid current*

Although the grid characteristics of Figs. 1 and 2 have been presented in logarithmic form to show their exponential nature, a linear grid-current plot is more suitable to demonstrate the production of distortion. Curve A of Fig. 4 is a control-grid characteristic plotted in this way with the bias needed to give 0·1 microamp of grid current used as the grid-voltage reference point.

A sinusoidal signal, B, with a peak-to-peak amplitude of 0·4 volt is shown at the bottom of Fig. 4. Each point on B is considered to be projected from the base line to the grid characteristic by a line parallel to G. The slope of G represents the slope of the impedance between the signal generator and the grid of the valve in accordance with the voltage and current scales used. In Fig. 4 the slope represents a series impedance of 0·1 megohm.

Waveform C in Fig. 4 is the distorted signal voltage applied to the grid of the valve. The voltage drop across the series impedance at any point in the excitation cycle is the voltage as read from the base scale traversed by the lines parallel to G.

Thus curve C of Fig. 4 represents the distorted signal produced by applying a 0·4 volt peak-to-peak sinusoidal input through a 0·1 megohm series impedance to the control grid of a valve drawing 0·1 microamp of positive grid current in the absence of a signal.

Grid-Current Equation

To obtain an equation representing the grid current in a typical a.f. amplifier, consider the circuit of Fig. 5.

Let the effective series impedance between generator and control grid be R_{AC}; i.e., $1/R_{AC} = 1/R_1 + 1/R_{DC}$ and let the valve be biased into the retarding-field region of its grid characteristic by E_{DC}, which includes the effect of contact-potential differences within the valve.

Further, let the generator output voltage be

$$\frac{R_1 + R_{DC}}{R_{DC}} E_{AC} \sin \omega t$$

so that, whatever the values of R_1 and R_{DC}, the alternating voltage applied to the grid of the valve in the absence of grid current is $E_{AC} \sin \omega t$.

It has been shown that, to a close approximation, when $E_{AC} = 0$ and $R_{DC} = 0$, the grid current

$$I'_{DC} = F\, I_s \exp. (-10 E_{DC}) \text{ amp.} \qquad (7)$$

If now the bias voltage is applied to the grid through E_{DC} the voltage drop across the resistor increases the negative bias on the valve and this reduces the current. Let the current in the presence of R_{DC} be I_{DC}, then

$$I_{DC} = F\, I_s \exp. \{-10\, (E_{DC} + I_{DC} R_{DC})\} \text{ amp.} \qquad (8)$$

Let E_{AC} have a finite value so small that it does not affect the average value of current. Then the current flowing in the grid circuit of the valve is:

$$I_{DC} + I_{AC} = F\, I_s \exp. \{-10\, (E_{DC} + I_{DC} R_{DC} + E_{AC} \sin \omega t)\} \text{ amp.} \qquad (9)$$

In general, however, the applied sinusoidal signal will increase the average value of grid current.

With R_{DC} and R_{AC} negligibly small let the ratio of current with applied signal to current without signal be D'.

$$\text{Then } D' = \frac{1}{2\pi} \int_0^{2\pi} \exp. (10\, E_{AC} \sin \omega t)\, dt \qquad (10)$$
$$= I_0\, (10\, E_{AC})$$

where I_0 is the modified Bessel function of the first kind of zero order [see for example Ref. (8) p. 103].

Similarly when $R_{AC} \neq 0$ the ratio

$$D = I_0 \{10\, (E_{AC} - I_{AC} R_{AC})\} \qquad (11)$$

since the voltage-drop across R_{AC} reduces the signal applied to the grid.

Now with the bias voltage applied through R_{DC} the

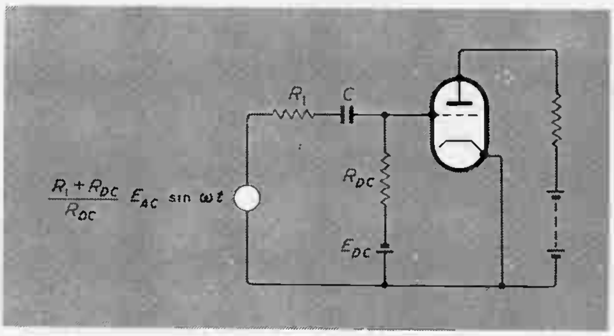


Fig. 5. *Circuit of a.f. amplifier*

increase in current due to the applied signal results in a greater negative voltage being developed across R_{DC} and thus in a smaller increase in current than the ratio D.

In the presence of an applied signal and with $R_{AC} \neq 0$ let the ratio of current when R_{DC} is of significant size to the current when R_{DC} is negligibly small be B, then

$$B = D \exp. \{-10\, I_{DC} R_{DC}\, (B - 1)\} \qquad (12)$$

Since the excursions of a signal applied to the grid result of necessity in an increase of average direct current by the ratio D as compared with the current at the operating point, and since the actual increase in current under the operating conditions under consideration is the smaller ratio B, the grid-current equation becomes

$$I_{DC} + I_{AC} = C\,F\,I_s \exp.\{-10\,[E_{DC} + I_{DC}R_{DC} + (E_{AC} - I_{AC}R_{AC}) \sin \omega t]\} \text{ amp.} \quad (13)$$

$$\text{where } C = \frac{B}{D} = \exp.\{-10\; I_{DC}R_{DC}\; (B-1)\} \quad (14)$$

The direct current and voltage effects are shown in Fig. 6 with the curve DFI_s exp.$(-10\,E_{DC})$ drawn for a particular value of applied alternating voltage.

Fig. 6 shows, in particular, the relationship between I_{DC}, the standing current in the grid resistor in the absence of a signal, BI_{DC}, the actual grid current flowing in the presence of a signal, and CI_{DC}, the grid current which when multiplied D times by the application of a signal, becomes equal to BI_{DC}. Curves similar to those of FI_s exp. $(-10E_{DC})$ and DFI_s exp. $(-10\,E_{DC})$ are published in valve data handbooks as diode detection characteristics for various signal levels.

Equation (13) expresses the direct and alternating currents flowing in the grid circuit of the valve in Fig. 5 and, although the signal applied to the circuit is sinusoidal, the harmonic components of the retarding-field current develop harmonic voltages across R_{AC} which must also appear between grid and cathode of the valve. Thus a solution of Equ. (13) would give the distortion of the signal applied to the valve.

Unfortunately, a solution of Equ. (13) cannot be obtained. Distortion has nevertheless been evaluated by determining the effect of applied signals on the operating point [i.e., the factor C in Equ. (13)], and then by a point-by-point investigation of the excursions of the signal voltage.

Distortion Analysis

The construction of Fig. 4 demonstrates the distortion introduced into a 0.2-volt peak signal when applied through a 0·1-megohm resistor to the grid of a valve drawing a standing grid current of 0·1 microamp.

The distortion, however, is a function of the geometry of the figure rather than of the particular values of the scales used. If, for example, the current values of the grid characteristic were doubled, which would not affect its law and, at the same time, the resistance of the series impedance were halved, the figure, and hence the distortion, would be unchanged.

Thus, for a given input voltage the distortion is constant so long as the product of standing current and series resistance is a constant.

By plotting input voltage against distortion for a limited range of $I_{DC}R_{AC}$ products it is therefore possible to present a wide range of possible operating conditions. The range chosen for subsequent investigation is $I_{DC}R_{AC} = 10^{-2}$, 10^{-3} and 10^{-4} volt, the 10^{-2} volt condition representing for example 'grid-leak bias' conditions with 0·1 microamp of grid current and an a.c. series impedance of 0·1 megohm, and the 10^{-4} volt condition representing perhaps 0·1 microamp of grid current with a series impedance of 1,000 ohms or other conditions such as 0·001 microamp of grid current and 0·1 megohm series impedance.

It was shown in Fig. 4 that for a given set of conditions the waveform at the grid of the valve can be obtained graphically, and from the waveform the distortion can, of course, be derived.

Without reconstructing the whole waveform, however, well-known techniques can be used to determine the magnitude of any number of distortion products for any set of conditions. For example, the magnitude of the first four harmonics (including the fundamental) and the d.c. component can be obtained from a knowledge of the voltage at five particular equally-spaced points on the grid swing[9].

To determine the change in voltage at the grid of the valve due to a given voltage increment at the generator end of the series impedance, assume that in Fig. 5 the input impedance of the valve is much greater than R_{DC} and that the time constant $C_1\,(R_1 + R_{DC})$ is sufficiently large for the charge on capacitor C_1 not to change appreciably during an a.f. cycle. These are conditions normally encountered.

Now let a small alternating voltage, such that in the absence of grid current the signal at the grid of the valve would be ΔE volt peak, be applied from the generator. The alternating retarding-field grid current will set up a voltage across R_{AC} and thus reduce the signal applied to the grid.

Initially $I_R = FI_s \exp.\{-10(E + I_R R_{AC})\}$ amp. At the instant when $+\,\Delta E$ volt is applied from the generator let the current increase by a factor P.

$$\text{Then } PI_R = FI_s \exp.\{-10(E - \Delta E + PI_R R_{AC})\} \text{ amp.} \quad (15)$$

$$\therefore \quad P = \exp.\{10[\Delta E - I_R R_{AC}\,(P-1)]\} \quad (16)$$

Similarly, when $-\Delta E$ volt is applied, let the current decrease a factor Q.

$$\text{Then } QI_R = FI_s \exp.\{-10\,(E + \Delta E + QI_R R_{AC})\} \text{ amp.} \quad (17)$$

$$\therefore \quad Q = \exp.\{-10[\Delta E - I_R R_{AC}\,(1-Q)]\} \quad (18)$$

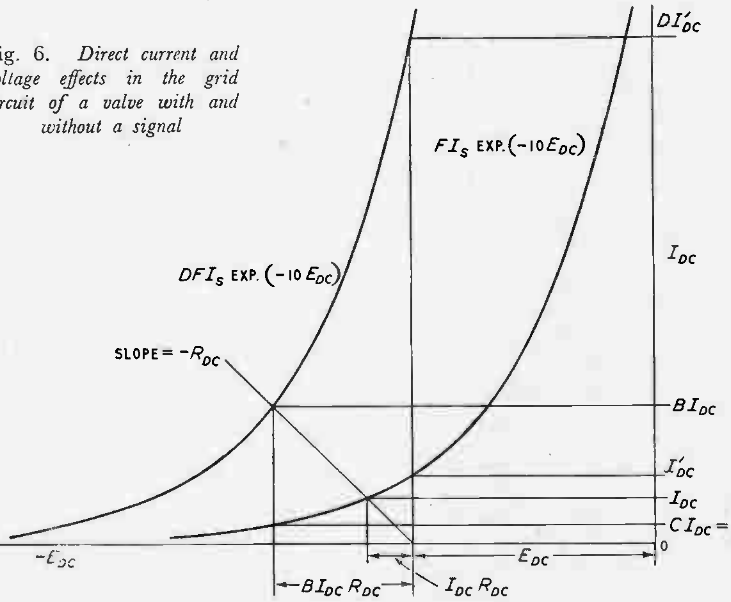


Fig. 6. *Direct current and voltage effects in the grid circuit of a valve with and without a signal*

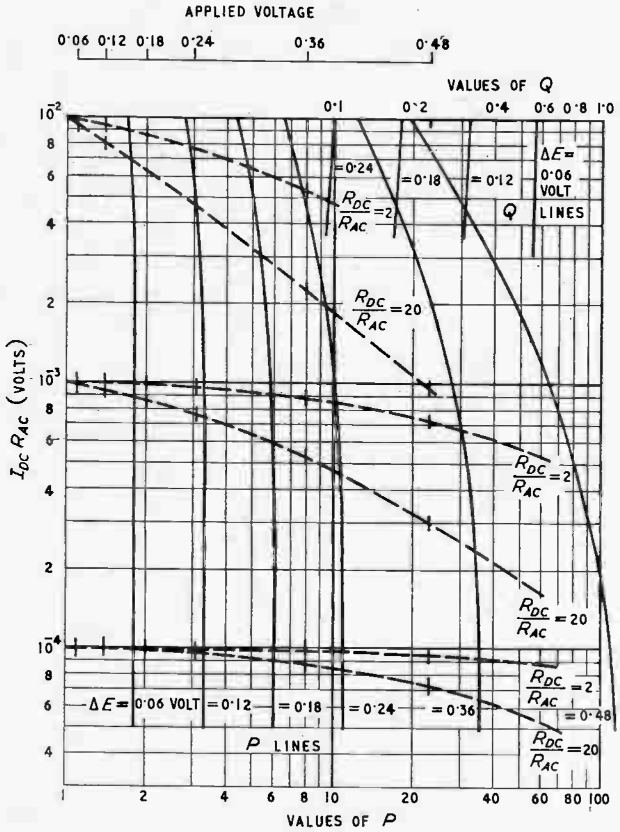


Fig. 7. *Nomogram for the evaluation of the factors C, P and Q*

Equations (15) and (17) give the current flowing in the grid circuit at the maximum and minimum peaks of an applied alternating voltage of peak magnitude ΔE. Equations (16) and (18) also contain the peak voltages actually applied to the grid, these being one-tenth of the power of the exponential function.

Thus a small alternating voltage of peak magnitude ΔE applied from the generator through a series impedance R_{AC} in the presence of a standing retarding-field current I_R, as previously defined, results in positive and negative peaks of $\{\Delta E - I_R R_{AC}(P-1)\}$ and $\{-\Delta E + I_R R_{AC}\,(1-Q)\}$ respectively being applied to the control grid of the valve.

The evaluation of P and Q has been effected by plotting $I_R R_{AC}$ against P and Q with ΔE as a parameter, for a convenient range of values of ΔE and $I_R R_{AC}$, as shown in Fig. 7, to be described below.

Variation of Current with Applied Signal

No account has been taken of the effect of the applied signal on the magnitude of the average value of grid current; i.e., the factor C in Equ. (13). This can be evaluated, however, by plotting D against C with values of $I_{DC}R_{AC}$ as a parameter.

To simplify this calculation, Equ. (11) has been reduced to $D = I_0\,(10\,E_{AC})$, the justification for the omission of the $I_{AC}R_{AC}$ term being that in practical cases valves are not used under conditions in which the loss of signal due to valve input conductance is more than a small fraction of the signal. (Subsequent calculations show that a maximum reduction of signal of 1 dB occurs under the conditions considered.)

In selecting suitable values of $I_{DC}R_{AC}$ the following considerations apply. As already suggested, the plotting of distortion for a limited range of $I_{DC}R_{AC}$ values can cover typical operating conditions. A complication is introduced, however, by the fact that the increase in current due to applied signals flows not in R_{AC}, but in R_{DC} which bears no direct relationship to R_{AC}, the distortion-producing resistor.

This effect can be overcome by the same technique of taking a limited number of values to cover the usual range of operating conditions. For example, two ratios of R_{DC}/R_{AC} of 2 to 1 and 20 to 1 have been taken, the former to represent the condition of equal anode load and following grid leak and the latter the other extreme of, say, a 0·1-megohm anode load with a 2-megohm following grid leak or a 0·25-megohm series resistance and a grid-leak-biased following stage with a 5-megohm grid leak.

Thus Equs. (16) and (18) are to be solved, not only for cases in which the applied signal has no effect on the average grid current but also with larger inputs, for a range of values of C dependent upon the applied input voltage and for R_{DC}/R_{AC} values of 2 and 20. This is done by means of Fig. 7, which consists of two nomograms drawn together for ease of use.

Use of Nomogram

In using Fig. 7 to evaluate P and Q there are two operations: first, the determination of $CI_{DC}R_{AC}$ from a knowledge of $I_{DC}R_{AC}$, of the value of the applied signal and of the ratio R_{DC}/R_{AC} and secondly the evaluation of P and Q after the operating condition $CI_{DC}R_{AC}$ has been determined.

To simplify the use of the nomogram, suitable 'Applied Voltages' are marked across the top. These points are the plot of $I_0\,(10\,E_{AC})$, as derived from Equ. 10, on the two-decade logarithmic scale 1 to 10^2 across the figure. Although a range of voltages which simplifies harmonic calculation has been selected and marked, the evaluation of C for any voltage within the range of the figure is possible.

To determine, for example, $CI_{DC}R_{AC}$ when $I_{DC}R_{AC} = 10^{-2}$ volt, the applied signal $= 0·36$ volt peak and $R_{DC}/R_{AC} = 20$, drop vertically from 'Applied Voltage' $= 0·36$ volt to the $R_{DC}/R_{AC} = 20$ line originating at $I_{DC}R_{AC} = 10^{-2}$ volt. It will be found that $CI_{DC}R_{AC} = 2·21 \times 10^{-3}$ volt, which is the operating condition.

P can now be determined by passing horizontally from $CI_{DC}\,R_{AC}$ to the 'P-line' corresponding to the applied voltage and reading P from the logarithmic scale at the bottom of the figure. For the example chosen, the 'P-line' for 0·36 volt intersects the horizontal line for $CI_{DC}R_{AC} = 2·21 \times 10^{-3}$ volt at $P = 22·5$. The positive peak of the voltage applied to the grid of the valve under these conditions can now be calculated from Equ. (16) as $0·36 - 2·21 \times 10^{-3} \times 21·5$ volt; i.e., 0·3125 volt. The negative peak is calculated separately in a similar manner using the 'Q-lines'.

Because the 'Q-lines' approach their limiting value much more rapidly than the 'P-lines' and because the values of Q decrease with increasing signal, it is

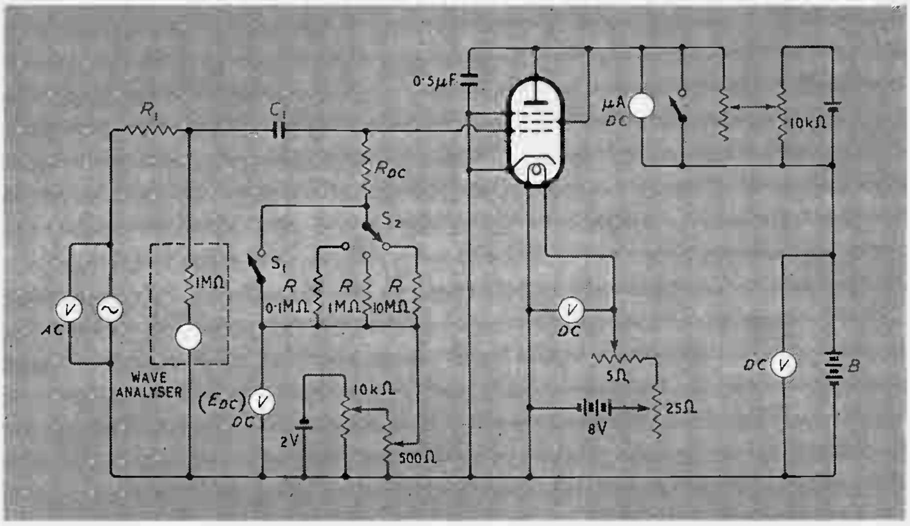


Fig. 8. *Test circuit for the measurement of grid-circuit distortion*

necessary only to plot a limited section. They are used in conjunction with the 'Values of Q' on top of the nomogram in a manner similar to that described for the 'P-lines'.

An interesting aspect of Fig. 7 is that the approximately horizontal R_{DC}/R_{AC} lines demonstrate the amount of 'biasing-back' of the valve that occurs with signal for the three initial $I_{DC}R_{AC}$ conditions of 10^{-2}, 10^{-3} and 10^{-4} volt.

Thus for a static $I_{DC}R_{AC}$ value of 10^{-2} volt and $R_{DC}/R_{AC} = 20$ (i.e., a grid-leak resistance value twenty times greater than the effective series impedance), the operating condition in the presence of an input signal of 0·48 volt is $I_{DC}R_{AC} = 9{\cdot}5 \times 10^{-4}$ volt, more than a ten times reduction in I_{DC}.

With a smaller grid leak and with smaller initial values of $I_{DC}R_{AC}$ the 'biasing-back' is reduced until with $I_{DC}R_{AC} = 10^{-4}$ volt and $R_{DC}/R_{AC} = 2$ it is negligible for signals up to 0·48 volt peak.

Experimental Confirmation

The circuit of Fig. 8 was used to obtain confirmation of the calculated results. A problem in devising a test circuit was the obtaining of accurate $I_{DC}R_{AC}$ values of 10^{-2}, 10^{-3} and 10^{-4} volt with R_{DC}/R_{AC} ratios of 2 and 20, without using unduly large values of grid-circuit resistance, without exceeding some few microamps of grid current (in order to maintain operation on the exponential part of the grid characteristic) and without introducing unwanted signals into the grid circuit, as several electronic microammeters when used in conjunction with the necessary biasing circuits were found to do.

This problem was overcome by using the valve under test in conjunction with appropriate grid-circuit resistors, to measure grid currents of 10^{-6}, 10^{-7} and 10^{-8} amp, while the parallel resistance of R, R_{DC} and the 1-megohm input resistance of the wave analyser was adjusted to 10^4 ohms. Different combinations of R_1 and R_{DC} were used to give R_{DC}/R_{AC} ratios of 2 and 20.

To obtain a distortion reading with a grid current of, for example, 10^{-7} amp, the switch S_1 was opened, the switch S_2 set to the 1-megohm resistor, the appropriate bias applied, as determined from the grid characteristic, and the anode-current meter set to zero by means of the shunting circuit. Switch S_1 was then closed and the anode-current meter readjusted to zero by means of the grid-bias control. If the required change in bias was 0·1 volt the grid current flowing after this adjustment was 10^{-7} amp. The signal was then applied to the grid and the distortion was measured. If the initial bias setting was incorrect, modifications were made and the procedure repeated.

Results

Calculated and measured results are shown in Fig. 9. Correlation is not perfect but, in view of the difficulties of the experimental technique, it is felt that verification of the analysis has been obtained. In both calculated and measured results significant harmonics up to the fourth have been included in the r.m.s. Total Harmonic Distortion as plotted.

In most cases the relative magnitudes of the harmonics were in general agreement, for example with a 0·48-volt signal, $I_{DC}R_{AC} = 10^{-4}$ and $R_{DC}/R_{AC} = 20$, calculated second, third and fourth harmonics were 0·42, 0·21 and 0·08 percent, while the measured figures were 0·32, 0·18 and 0·06 percent respectively.

The shape of the distortion curves is of interest and is due to the following factors. In the absence of 'biasing-back' with signal, due to additional negative bias being developed across the grid resistor in the presence of a signal (see Fig. 6) the distortion curves tend to increase sharply as the signal increases. This curvature is offset in varying degrees, however, by the reduction in distortion due to the signal-generated bias for high values of $I_{DC}R_{AC}$ and R_{DC}/R_{AC}. For the curve $I_{DC}R_{AC} = 10^{-2}$ volt and $R_{DC}/R_{AC} = 20$ the increase of bias with signal completely compensates at high inputs for the tendency for distortion to increase with increasing signal voltage.

This reduction in distortion, however, is applicable only to steady-state conditions. In normal amplifier usage instantaneous distortion will vary with the charge on the grid-coupling capacitor between the limits of the distortion applicable to the R_{DC}/R_{AC} ratio in use and a maximum which would occur in the absence of any signal-developed bias across the grid leak. The variation of instantaneous bias with signal will in fact add to the signal a secondary type of distortion particularly noticeable on square waves.

To interpret the curves of Fig. 9 in terms of practical circuits, a 'grid-leak biased' a.f. amplifier with grid current of 0·1 microamp and series grid impedance of 0·1 megohm ($I_{DC}R_{AC} = 10^{-2}$ V) could be expected to develop about 2% distortion in its grid circuit for an applied signal as small as 0·1 volt peak.

Alternatively, if high fidelity were required from a resistance-capacitance coupled stage at 0·5 volt peak input with a 0·5-megohm anode load in the preceding stage and with a 1-megohm grid leak, then the control-grid current would need to be smaller than 3×10^{-4} microamp, since at this value of grid current the grid-circuit distortion for this stage alone would be about 0·5%.

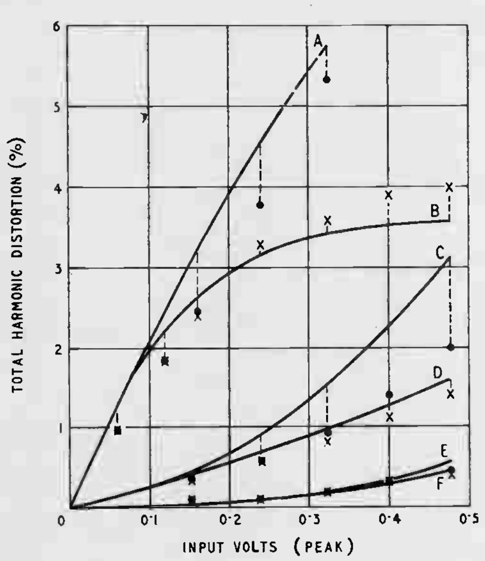
Signal Damping

The degree of signal reduction due to the finite input impedance of the valve is readily obtainable during the distortion calculations and is found to be approximately independent of signal level for a given $I_{DC}R_{AC}$ product. The approximate losses are 1 dB, 0·25 dB and 0·05 dB for $I_{DC}R_{AC}$ products of 10^{-2}, 10^{-3} and 10^{-4} volt respectively.

Relationship between Bias and Grid Current

While this analysis has been of necessity carried out with reference to values of control-grid current, valve operating conditions are invariably set up for particular values of control-grid bias. The relationship between bias and current is, however, dependent on many factors such as valve type and construction, valve processing schedules, age of valve and type of service, applied voltages, factors causing reverse grid current, and other less important considerations.

Fig. 9. *Calculated and measured values of total grid-circuit harmonic distortion.* $R_{DC}/R_{AC} = 2$ *for curves A, C and E*; $= 20$ *for curves B, D and F,* $I_{DC}R_{AC} = 10^{-2}$ *volt for curves A and B,* 10^{-3} *volt for curves C and D, and* 10^{-4} *volt for curves E and F*



However, since recommendations are to be made for the avoidance of grid-circuit distortion, investigation is necessary only into conditions likely to lead to maximum grid current. Thus, since the grid current of valves subjected to normal ageing schedules falls with valve usage under fixed operating conditions, only the grid current of new valves need be investigated.

Such an analysis has been carried out on the 'grid-current cut-off' bias of more than a thousand unused valves of different types. The 'grid-current cut-off' bias is the bias required to reduce grid current to 0·2 microamp, a value in the retarding-field region, and measured in the Amalgamated Wireless Valve Company at nominal heater voltage and without potentials applied to other electrodes.

Under these conditions five hundred 6AU6 valves showed a mean 'grid-current cut-off' bias of —0·97 volt with a standard deviation of 0·17 volt. Corresponding figures for 337 6AV6 high-mu triodes were —0·72 volt and 0·28 volt, for 100 6SJ7GT valves —0·81 volt and 0·17 volt and for 72 6BQ7A triodes —0·85 volt and 0·14 volt.

The influence of potentials applied to other electrodes varies considerably with individual valve types. The retarding-field grid current of a 6SJ7GT may be decreased fifty times by increasing the grid 2 and anode voltage from 0 to 100 volts. On the other hand, with the close-spaced 6BQ7A an increase of anode voltage from zero may result in an initial two or three times increase in control-grid current, followed by a decrease to the original value when the anode voltage has reached approximately 100 volts. With the 6AU6 and 6AV6 an increase in triode anode voltage from 0 to 100 volts results in retarding-field grid current reductions of the order of twenty times and four times respectively.

Accordingly, the value of 'grid-current cut-off' determined as above without potentials applied to outer electrodes can be used conservatively as the bias required to reduce control-grid current to 0·2 microamp in the majority of valves operating with normal voltages applied to other electrodes.

On the assumption that a standing grid current of 10^{-9} amp ($I_{DC}R_{AC} = 10^{-4}$ volt with 0·1-megohm series impedance) will give satisfactorily low grid-circuit distortion for signals up to 0·25 volt, a minimum bias figure of —1·8 volt can now be recommended. This value is the sum of approximately —0·5 volt to reduce the current from 0·2 to 0·001 microamp and —1·3 volt to allow for 'grid-current cut-off' bias plus twice the standard deviation. Under these conditions not more than one valve in fifty should exceed the desired maximum grid current.

Reverse Grid Currents

The effect of reverse grid currents on the value of bias required to avoid grid-circuit distortion has been ignored for the following reasons:

(1) Of 1,009 valves examined, only eight—three oi these from one day's production—had reverse grid currents of 0·2 microamp or more when operated at maximum ratings.

(2) Audio-frequency amplifier valves operated under low-bias conditions are almost invariably resistance-

coupled. Since gas current is approximately proportional to anode current and to the square of the anode voltage, this low-current, low-voltage operating condition greatly reduces the tendency for reverse grid current to flow.

(3) Since gas current increases with increasing anode current (i.e., with decreasing negative bias) any value of gas current likely to be present in a valve minimizes the curvature of the positive grid-current characteristic and thus reduces the grid-circuit distortion. The condition for maximum distortion is thus a valve with minimum reverse grid current.

Recommendations

With low-level a.f. amplifiers, negative grid bias is usually kept as small as possible because maximum gain is obtained from resistance-coupled pentodes in this condition and because high-mu triodes cut-off rapidly as bias is increased.

For these reasons existing valve manufacturers' recommendations usually specify bias values which are inadequate in the light of the preceding analysis. It is realized that these recommendations are accompanied by satisfactory values of measured distortion, but the reason for this, it is suggested, is that the measurements are made with zero driving-source impedance and thus do not include the grid-current distortion that would occur in more practical conditions.

To restrict grid-circuit distortion to a maximum of 0·1% the following recommendations are made:

(1) For valve types in which it is not essential to use the smallest possible bias; e.g., normal resistance-coupled pentodes. *For signals up to* 0·25 *volt peak and for driving-source impedance not greater than* 0·1 *megohm the recommended bias is* −1·8 *volt.*

Where negative bias must be kept to a minimum (e.g., with high-mu triode amplifiers) the following more detailed recommendations apply.

(2) For signals not greater than 5 millivolts peak the $I_{DC}R_{AC}$ product should not exceed 10 millivolts;

(3) For signals between 5 and 50 millivolts peak the $I_{DC}R_{AC}$ product should not exceed 1 millivolt;

(4) For signals between 50 and 250 millivolts peak the $I_{DC}R_{AC}$ product should not exceed 100 microvolts.

To determine I_{DC}, allow −1·3 volt of bias to reduce it to 0·2 microamp. Each additional −0·1 volt of bias will reduce the grid current to 0·37 of the original figure.

For applications in which greater distortion can be tolerated, larger $I_{DC}R_{AC}$ products, and thus smaller values of negative bias, can be used in accordance with the results set out in Fig. 9.

Acknowledgements

The author wishes to thank the management of the Amalgamated Wireless Valve Co. Pty. Limited, for permission to use the results of measurements on production valves, and the staff of the Company, and particularly of the Applications Laboratory, for assistance during the preparation of this paper, which is based on the results of research carried out in partial fulfilment of the requirements for the degree of Master of Engineering in the N.S.W. University of Technology.

REFERENCES

[1] H. B. Michaelson, "Variations of Grid Contact Potential and Associated Grid Currents", *J. Franklin Inst.*, June 1950, Vol. 249, No. 6, p. 455.

[2] J. A. Darbyshire, "Initial Velocity Currents in Thermionic Valves", *Proc. Phys. Soc.*, May 1941, Vol. 53, Part 3, p. 219.

[3] G. D. O'Neill, "Contact Potential and Retarding Field Measurements", *Sylvania Technologist*, Part 1, July 1949, Vol. 2, No. 3, p. 13, Part 2, October 1949, Vol. 2, No. 4, p. 12.

[4] G. Hermann and S. Wagener, "The Oxide-Coated Cathode", Vol. 2, Chapman and Hall, London, 1951. (Textbook.)

[5] W. Schottky, *Ann. D. Phys.*, 1914, Vol. 44, p. 1011.

[6] K. R. Spangenburg, "Vacuum Tubes", McGraw-Hill, N.Y. (Textbook.)

[7] J. Yarwood and D. H. Le Croissette, "D.C. Amplifiers: Methods of Amplifying and Measuring Small Direct Currents and Potentials", *Electronic Engineering*, Part 1, January 1954, Vol. 26, p. 14; Part 2, February 1954, Vol. 26, p. 64.

[8] N. W. McLachlan, "Bessel Functions for Engineers", Oxford University Press, 1934. (Textbook.)

[9] D. C. Espley, "The Calculation of Harmonic Production in Thermionic Valves with Resistive Loads", *Proc. Inst. Radio Engrs*, October 1933, Vol. 21, p. 1439.

CONFERENCE ON AUTOMATION

Proposals have been made by a number of professional associations for a joint conference on automation and computation. The following fields of interest would be covered:

The engineering applications of automation techniques.

The development and application of computers, automatic controls and programming techniques.

The sociological and economic aspects of automation and computation procedures.

The proposals for the conference, which were made at an exploratory conference arranged by the Institution of Civil Engineers, the Institution of Mechanical Engineers and the Institution of Electrical Engineers, are being considered by about twenty organizations.

COMPUTER EXHIBITION

An electronic computer exhibition, to include data-handling equipment of all kinds, will be held at Olympia, London, from 28th November to 4th December 1958.

VISUAL PROBLEMS OF COLOUR

A symposium under this title is to be held at the National Physical Laboratory from 23rd to 25th September 1957. Subjects to be dealt with include pigments, brightness and colour matching, colour vision, subjective colour measurements, and colour theories. There will be over 30 papers in all. Attendance will be by invitation, and those interested should write to the Director, National Physical Laboratory, Teddington, Middlesex.

GRADUATE COURSE IN INFORMATION ENGINEERING

A 12-months course in information engineering for honours graduates in electrical engineering will be held at Birmingham University, starting in October 1957. Subjects comprise electrical communications, electronic computers and automatic control systems. There will be a formal written examination; and a 3 months individual project. Graduates who satisfy the examiners for the course will receive the degree of M.Sc.

A booklet describing the course is available from the University of Birmingham, Electrical Engineering Department, Edgbaston, Birmingham 15.

AUSTRALIAN RADIO CONVENTION

The Institution of Radio Engineers of Australia is to hold its annual convention at the Hotel Australia, Sydney, from October 21st to 26th 1957. There will be 40 lectures and a display of equipment and components of Australian manufacture.

PROTON RESONANCE AND THE MEASUREMENT OF MAGNETIC FIELDS

Angular momentum and magnetic moment are both possessed by an electron rotating in a circular or elliptical orbit, and the same is true for an electron or proton simply spinning about its own axis. This is the principle underlying a variety of physical phenomena, from the Zeeman splitting of optical spectral lines in a magnetic field, and the gyromagnetic effects in which bodily rotation accompanies magnetization, to the paramagnetic (or electron) resonance and nuclear resonance effects which are studied under the heading of microwave and radio-frequency spectroscopy. Any kind of general discussion dealing with, say, an electron in a given atom or a proton in a given nucleus would be complicated by the very involved interrelations between it and its neighbours ; and that is rather too much in the province of pure atomic physics. In the case of proton resonance (or, if you prefer it, nuclear resonance of hydrogen) matters are simplified experimentally by the fact that the range of frequencies most commonly exploited for this purpose is the ordinary radio-frequency range. And the theory is so closely analogous to the classical and very early quantum-theory explanations of the Zeeman effect that it can be explained without delving too deeply into modern abstractions.

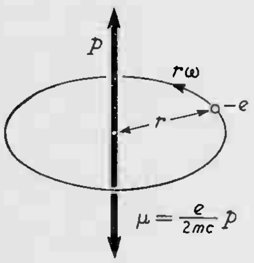


Fig. 1. *Electron-orbit as an Ampère 'magnetic shell'; as the charge is negative, μ and p are drawn in opposite senses*

I can still remember the difficulty I first experienced not in understanding the resonance effect but in actually believing it. The order of energy seems all wrong. Millions of electron-volts, billions of electron-volts, these are the figures we associate with nuclear changes ; but a quantum of radio-frequency radiation carries something like 10^{-8} of an electron-volt, and is about 10^{-3} of the thermal agitation energy kT at ordinary temperatures. The reason is that what one might call large-scale uprootings and transitions from one energy level to another are not involved ; the intervention of a magnetic field does not bring new major energy states into being, but causes minor separations or splittings of those already existing. If the ordinary energy states are likened to the successive floors of a building, the splitting resembles slight irregularities between adjacent floorboards.

It may seem almost irrelevant to start off with the Zeeman effect and the measurement of the gyromagnetic ratio ; but this is the easiest way of treating the general principle. Be patient if I say nothing about spin to begin with ; spin itself was only discovered when it was found that this treatment did not always work.

Magnetic Moment and Angular Momentum

Let us take for simplicity an electron, charge e e.s.u. (e/c e.m.u.) describing a circular orbit of radius r cm with angular velocity ω rad/sec, as shown in Fig. 1. Since e/c e.m.u. of charge pass round every $2\pi/\omega$ sec, the equivalent *current* in e.m.u. is $e\omega/2\pi c$. By Ampere's magnetic shell theorem, the magnetic moment, μ, of the rotating electron is $\frac{e\omega}{2\pi c} \times \pi r^2$; thus,

$$\mu = \frac{e\, r^2 \omega}{2c}.$$

Now, the angular momentum p is $mr^2\omega$, where m is the mass of the electron.

Hence, $\mu = \frac{e}{2\, mc}\, p$, and the magnetic moment is proportional to the angular momentum. Both p and μ are vectors, the direction being at right angles to the plane of the rotation. The expression $e/2mc$ is called the electron's gyromagnetic ratio ; the fact that it involves only the universal constants e, m and c, and is independent of r and ω, suggests that the result of the above calculation may apply more generally—though quite obviously with some modification, as p cannot be written simply as $mr^2\omega$ in other cases. What is indeed found for the *spinning* electron is that, for the spin angular momentum and magnetic moment, the gyromagnetic ratio γ is given by $\gamma = g(e/2mc)$; and

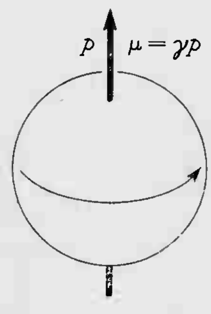


Fig. 2. *Spinning proton with magnetic moment μ and angular momentum p as vectors in the same direction*

for the spin angular momentum and magnetic moment of the proton, $\gamma = g(e/2Mc)$, where M is the mass of the proton. The coefficient g is called the Landé splitting factor ; its value is very nearly 2 for electron-spin, and about 5·6 for proton-spin, while it is simply 1 for the orbital case considered above. Some very advanced theory is needed to compute g, or to relate the measured values to an atomic model (according to the way you look at it).

In general (Fig. 2), for every case of a spinning particle

$\mu = \gamma p$

where p is the spin angular momentum, μ the magnetic movement (directed in the same or opposite sense as p according to sign of charge), and γ the appropriate gyromagnetic ratio.

Measurement of the Gyromagnetic Ratio for Electron-Spin

The laws of motion and the law of conservation of angular momentum show that the magnetization of a ferromagnetic should be accompanied by a mechanical torque and, conversely, that rotation of a specimen should produce magnetization. The first process is called the Einstein-de Haas effect, and the second the Barnett effect. Taking the first of them, the application of a field B gives a couple proportional to μB on each μ, tending to align μ with B ; but there is also p to consider, and the effect of the couple is to cause the axis of rotation to precess about the direction of B. Each little electronic magnet-cum-gyroscope has thus gained angular momentum about an axis parallel to B ; but the angular momentum of the whole system must be conserved, so the specimen as a whole experiences a couple in the opposite sense, tending to rotate it bodily.

Delicate apparatus is, of course, needed to detect and measure such a couple ; a full description of thc experiments of Chattock and Bates, and Sucksmith and Bates, is given in L. F. Bates' "Modern Magnetism" (Cambridge University Press). The results can be summarized for our purposes by saying that in the cases where μ and p are certainly attributable to spin, the value of g for electrons turns out to be very nearly 2, and the value of γ as $g(e/2mc)$.

For proton-spin, the resonance method, with *known* B, is used to determine g.

In the whole of this article B stands for the *flux-density* of the field, the quantity which is, in the absolute c.g.s. electromagnetic system, measured in gauss.

Zeeman Effect in Optical Spectra

Viewed in a direction at right angles to B, lines in the spectrum of a light-source within the field are seen as triplets, Fig. 3. Besides the ordinary line at frequency ν, two flanking lines each separated by a frequency $\Delta\nu$ from the undisplaced line appear. 'Ordinary' was perhaps the wrong term to use, since the ν and the $\nu \pm \Delta\nu$ lines are plane polarized.

The magnitude of the separation is given by

$$\Delta\nu = \frac{e}{4\pi mc} B \quad .$$

Larmor showed, purely on the basis of classical mechanics, that an electron *orbit* would precess in a magnetic field with an angular velocity

$$\omega_0 = \tfrac{1}{2}\frac{e}{mc} B \quad .$$

For, supposing the orbital motion referred to a precessing co-ordinate axis, the electron experiences a Coriolis force $2mr\omega_0^2$ at right angles to its path, and also an electromagnetic force $Ber\omega_0/c$. The condition for equilibrium with respect to this axis—that is, for the maintenance of the precessing motion—is

$$2mr\omega_0^2 = Ber\omega_0/c,$$

giving the expression for ω_0.

Since the frequency of rotation of the electron is $\omega_0/2\pi$, the precession frequency of Larmor's calculation is the same as the $\Delta\nu$ of the Zeeman effect. This calculation then, establishes the relation between a *frequency* that can be measured, the flux density B of a magnetic field, and certain universal constants.

The expression $e/2mc$ is the gyromagnetic ratio γ for the orbital electron. The angular velocity of precession is thus given by $\omega_0 = \gamma B$.

For electron-spin or proton-spin, the precession is that of the spin-axis about the direction of B, and the appropriate value of γ is used ; but exactly the same formula holds. *Always* the precession angular velocity in a magnetic field is γB.

It may seem a little odd that we have managed so far without invoking h ; this comes into things soon enough, but the reason why classical mechanics has served so far is that we are dealing with something as fundamental as the laws of mechanics which is quite as general.

Numerical Values : the Bohr Magneton

We use the values $6{\cdot}6 \times 10^{-27}$ units for Planck's constant h ; $4{\cdot}8 \times 10^{-10}$ e.s.u. for the electronic charge

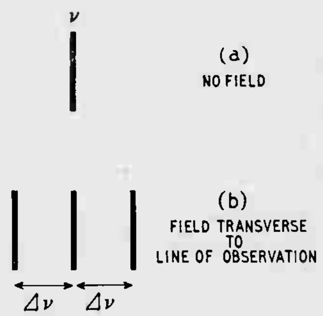


Fig. 3. *Illustrating the Zeeman effect; here the frequency* change $\Delta\nu$ *is calculated on Larmor's theory as the frequency of precession of an electron orbit in a magnetic field. This is relevant as an analogy, for similar considerations give the frequency of precession of the proton spin-axis in a magnetic field*

e ; 9×10^{-28} gm for the electronic mass m, and taking the proton mass M to be $1836m$; 3×10^{10} cm. sec^{-1} for the speed of light in vacuo c. Then the combinations $e/2mc$ for the electron, and $e/2Mc$ for the proton are $8{\cdot}8 \times 10^6$ and $4{\cdot}8 \times 10^4$ units respectively. And, using the proper g-values 2·0 and 5·6, the gyromagnetic ratios are :—

for the electron, $\gamma = 1{\cdot}77 \times 10^7$ radian sec^{-1} gauss^{-1},
and for the proton, $\gamma = 2{\cdot}67 \times 10^4$ radian sec^{-1} gauss^{-1}.

As $\omega_0 = 2\pi\nu_0$, for the orbital electron and the Zeeman splitting $\nu_0 = \Delta\nu = 1{\cdot}5 \times 10^6\ B$. For the spinning electron, the appropriate *precession* frequency is $\nu_0 = 3{\cdot}0 \times 10^6\ B$; and for the proton $\nu_0 = 5 \times 10^3\ B$.

Supposing then that we are restricted to methods of producing and measuring frequencies in the range between 10^6 and 10^8 c/s, the values of B that could be determined by resonance methods would be:

for electrons, from 0·3 to 30 gauss, and

for protons, from 200 to 20,000 gauss.

Now, although so far quanta have not come into things, resonance involves the absorption of energy which must occur by quanta. Since the energy of frequency ν_0 can only change by finite increments $h\nu_0$, corresponding limitations hold for possible changes in p and in μ. Really, in order to concentrate on the Larmor precession idea, things have been treated in an obsolete kind of way; for it should have been stated at the beginning that p can only change by whole multiples of $h/2\pi$ for an orbital electron, and by $\frac{1}{2}\,h/2\pi$ for electron or proton spin. Since μ is proportional to p, μ can only change by corresponding steps. Forgetting g for the moment, if $\mu = ep/2mc$, and p is to be a multiple of $h/2\pi$, then μ must be a multiple of a quantity called the Bohr magneton, $\beta = eh/4\pi mc$, which is about $9 \cdot 3 \times 10^{-21}$ units. Similarly, substituting M for m, the nuclear magneton is $\beta_N = eh/4\pi Mc$, about 5×10^{-24} units; all nuclear magnetic moments are multiples of β_N.

There is thus another way of regarding the precession of the spin axis about the direction of the field. The value of ω_0 is determined by the condition that the component of p parallel to the field shall be $\frac{1}{2}h/2\pi$ (Fig. 4); and, taking g into account now, and thinking of protons only from now on, they acquire a magnetic-moment component $g\beta_N$ parallel to B, absorbing energy in the process.

The energy quantum absorbed is then

$$\Delta E = g(eh/4Mc)B, \text{ or } g\beta_N B,$$

and the corresponding frequency, since $\Delta E = h\nu_0$, is

$$\nu_0 = g\beta_N B/h.$$

Resonance

In the proton-resonance method for measuring strong magnetic fields, a radio-frequency alternating field $B' = B_1 \sin \omega t$, where ω is modulated over a range embracing ω_0 with, say, a 50-c/s repetition, is applied at right angles to B (Fig. 5). A small tube of water (the proton supply) is placed inside the coil L_0. As ω is varied, resonance occurs when $\omega = \omega_0$. Then, quanta of energy $g\beta_N B$ are being accepted for the energy-jump ΔE which gives magnetic-moment components parallel to B. From the simplest point of view, this is a straightforward case of resonance between coupled circuits, with

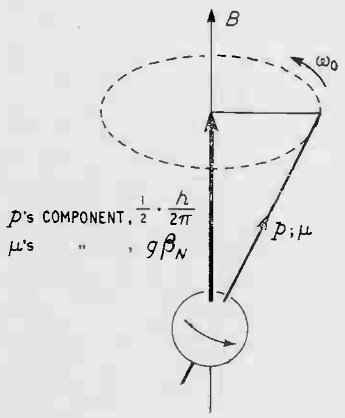


Fig. 4. *According to the quantum theory, the angular velocity of precession ω_0 is such that the component of μ parallel to B is gB_N*

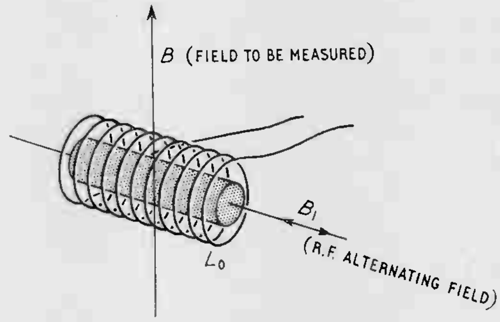


Fig. 5. *Scheme of experiment to measure B; the r.f. field of varying frequency is applied at right angles to B, and resonance detected by the change in Q of L_0*

L_0 as the primary and the protons as the secondary; and the energy transfer at resonance occurs with maximum damping of L_0, by which ω_0 is detected. As with ordinary coupled circuits, conditions for optimum coupling can be found. Something analogous to the usual Q, as a measure of the rate at which the secondary can dissipate energy, is involved; but this has to be expressed in terms of the properties of the proton. Protons which have absorbed a quantum ΔE will remain for an appreciable time in possession of the energy, and can then dispose of it only to the surrounding material. The average lifetime in the higher energy state is called the spin-lattice relaxation time, T_1, and may be anything between 10^{-4} sec and several hours under different conditions. For protons in water, T_1 is about 2·3 sec. There is a second effect, the loss of that regimented coherence that the field has imposed on the protons themselves, which loss occurs as they interchange energy with one another; the spin-spin relaxation time T_2, measuring the average time before this process takes place, is about 10^{-4} sec. These two relaxation times, together with the amplitude of B_1, determine the sharpness of resonance and the general behaviour of the protons as a 'secondary circuit'.

On general grounds, one would expect a long relaxation time to favour a narrow resonance peak and also a small energy transfer. For once a proton has absorbed its quantum it is out of action for the relaxation time, and can do no further absorption until released. Also, if the relaxation time is long and B_1 is large, then the whole of the protons may all be in an excited state together; absorption then ceases, and the material is saturated.

Taking line-width first, this has been shown to depend on $1/T_2$. If T_1 is large compared with T_2, then the spin-spin time is the decisive one. The line width, $\Delta\nu$, is then given by $\Delta\nu = 1/\pi T_2$. If T_2 is 10^{-4} sec, then $\Delta\nu$ is about 3000 c/s, corresponding to a spread in B of about 1 gauss.

For the other important quantities, the optimum value of B_1 is $1/(g\beta_N\sqrt{T_1 T_2})$ the signal-to-noise ratio is proportional to $1/\sqrt{T_1}$; the power absorbed at resonance depends on $1/T_2$, $\nu_0 B_1/B$, and T_1/T_2, being reduced by an increase in each of these factors.

While, therefore, the long spin-lattice relaxation time for water is in the first instance an advantage as favouring a sharp resonance peak, in the end it turns out to be desirable to have T_1 and T_2 of about the same order, both to increase the damping of L_0 which we use to

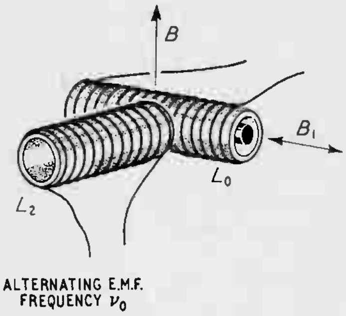


Fig. 6. *Detection of nuclear induction in L_2, perpendicular to L_0*

detect resonance, and also to prevent saturation. A very powerful feature of the proton-resonance method is that T_1 can be reduced to any desired value by adding to the water-specimen a suitable quantity of a paramagnetic salt such as ferric nitrate or manganese sulphate.

The Resonance Signal

The absorption of energy at resonance, with consequent damping of L_0, can be regarded in several ways —as an increase in the Q of the specimen, a decrease in the Q of the L_0 circuit, or an increase in the susceptibility χ of the specimen. The last of these raises an interesting point. Supposing that the specimen fills the coil L_0 completely, then its inductance becomes

$L = L_0\ (1 + 4\pi\chi)$, and χ and L both reach their maximum values at resonance. Now, a reactance cannot absorb energy, so it looks as if this may not get us far. But, writing χ as a complex susceptibility $\chi_1 - j\chi_2$, it is seen that the out-of-phase component χ_2 is associated with the damping of L, since $(-j \times j) = -1$.

As far as the measurement of B is concerned, the only observation that has to be made is the value ν_0 of the resonance frequency. The accuracy of this depends ultimately on the calibration of the B_1 oscillator, being of the order 1 in 10^4 to 1 in 10^5 ; that is, in some cases of the order of one milligauss. It should be added that, although round figures have been used in this article for the universal constants involved in β_N and γ, the values of these and also of the splitting factor g are known to an accuracy of about a few parts in a million.

The old question now arises—what do we mean by resonance anyhow ? There is no doubt about this, of course, in the case of the protons themselves, but is ν_0 to be detected as a maximum-amplitude effect or a phase-quadrature effect in the L_0 circuit ? Either procedure may be adopted. The article on "Methods of Measuring Strong Magnetic Fields", by J. L. Symonds in the 1955 volume of the Physical Society's "Reports on Progress in Physics" describes a number of circuits that have been used ; D. J. E. Ingram, in "Spectroscopy at Radio and Microwave Frequencies" mentions one simple one for detecting amplitude resonance.

Nuclear Induction: Nuclear Precession

Instead of detecting resonance in L_0 itself, by its own damping, a second coil L_2 at right angles to both B and L_0 can be used to pick up a signal (Fig. 6). For, once resonance has been established, the magnetic moments precessing at frequency ν_0 give an induced e.m.f. in L_2. This nuclear induction effect does not seem itself to have been used directly for magnetic-field measurement, but it comes into the nuclear precession technique that is being developed for determining *very weak* magnetic fields, particularly for geophysical surveys. The general idea of this is to take advantage of the long spin-lattice relaxation time T_1 of protons in water by catching them in the energized state after the strong aligning field has been removed; they are then able to precess about any other magnetic field, however weak. Thus, to measure the earth's field B, a strong magnetizing field B_0 of the order of several hundred gauss is applied at right angles to B, by an appropriately situated coil not shown in the figure [Fig. 7(a)]. Then, B_0 is quickly reduced to zero in a time short compared with T_1. The nuclear magnetic moments previously set in the B_0 direction now precess about B, with frequency given by the usual equation $h\nu = g\beta_N B$.

If B is about 0·5 gauss, then ν is of the order 2 kc/s, and an induced voltage of this frequency is picked up by a coil set as L_2 in Fig. 7. In weak fields, this is not a radio-frequency or even an audio-frequency effect—it is what we should think of as an ordinary alternating voltage. The specimens used are very much larger than in ordinary proton resonance ; the people engaged in this work speak of them as 'bottles' of water. The accuracy with which B is determinable by this method is about 1 part in 15,000.

The method has been described in an article by G. S. Waters and G. Phillips in *Geophysical Prospecting*, Vol. IV, No. 1, March 1956. With a 500 c.c. bottle of water, and B_0 = 100 gauss, ν was found in England to be about 2,000 c/s in the earth's field. Its value is enhanced by the fact that the decay time of the nuclear precession depends on the *field gradient* across the specimen, being smaller in large gradients and, with the apparatus described, these authors were able to measure directly gradients in the range 5–100 microgauss/cm.

The effect of reducing T_1 by using weak solutions (0·001 N , 0·002 N) of ferric nitrate is also discussed in the article.

The conclusion is that this reduces the accuracy of the method, and of course for gradient-measuring purposes the whole decay would be much too rapid in any case. With distilled water, the process of decay can be followed on an oscilloscope display for 5–10 sec. Another advantage of this method for field work is that the specimen can be taken considerable distances, 100 feet or so, from the recording apparatus, communication between the two being by coaxial cable.

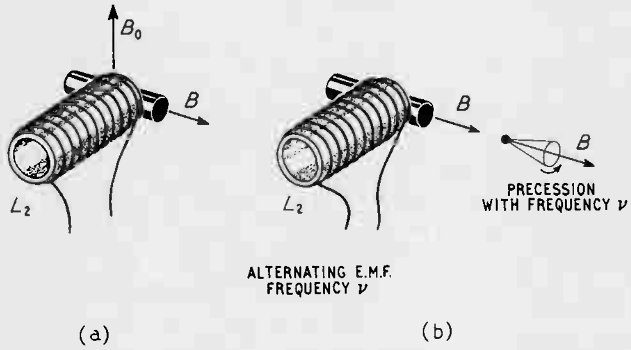


Fig. 7. *Nuclear precession. When B_0 is switched off, during the relaxation time T_1 the magnetic axes of the protons precess about B, generating a low-frequency e.m.f. in L_2*

Noise in Negative Feedback Amplifiers

By C. N. W. Litting*, B.Sc., Ph.D., A.M.I.E.E., A.Inst.P.

SUMMARY. *The noise originating in the input circuit and other points in an amplifier is discussed, with particular reference to the signal-to-noise ratio at the output. The effect of negative feedback under various conditions is considered, and it is concluded that under certain conditions a great improvement in signal-to-noise ratio may be obtained by using feedback. Other methods of improving the performance are mentioned and it is shown that, in theory, similar results can be obtained without the use of feedback. The other methods are, however, less elegant and in some cases impracticable.*

It is often stated that the noise output from an amplifier may be reduced by means of negative feedback. Statements of this nature are extremely vague and it is important to know under what conditions an improvement in signal-to-noise ratio may be obtained by employing feedback.

Considering a feedback amplifier, indicated diagrammatically in Fig. 1, we have the well-known expression giving the gain of the feedback amplifier as

$$\frac{E_0}{E_i} = \frac{-A}{1 + A\beta} \quad \text{(where } A \text{ is positive)}$$

Any noise or fluctuations introduced before the input of the amplifier will, of course, receive the same treatment as the signal and hence feedback cannot alter their effect. Of more importance is the case of fluctuations arising in the amplifier itself, whether they are true random fluctuations, pick-up from external sources, or hum introduced from the heater and h.t. supplies.

Noise Originating Internally in the Amplifier[1]

If we represent a fluctuation introduced at a point in the amplifier circuit by an equivalent noise generator E_n we have an equivalent circuit as shown diagrammatically in Fig. 2, where $A_1A_2 = A$. The noise at the output is then given as

$$E_{n0} = \{-A_1\beta\, E_{n0} + E_n\}A_2$$

$$\text{or } E_{n0} = E_n \frac{A_2}{1 + A\beta} \qquad \ldots \quad \ldots \quad \ldots \quad (1)$$

That is, the noise output is less than it would be if the feedback were removed and, in fact, if $A_2 < (1 + A\beta)$ the noise output (E_{n0}) is less than the noise injected into the amplifier (E_n).

Although the feedback has thus reduced the output noise it must be remembered that it has also reduced the signal and the important criterion is the signal-to-noise ratio. Considering only this source of noise it is obvious that the signal-to-noise ratio at the output is

$$R_{FB} = \frac{E_{s0}}{E_{n0}} = E_{si}\frac{A}{1 + A\beta} \cdot \frac{1 + A\beta}{E_nA_2}$$

$$= \frac{E_{si}}{E_n}\frac{A}{A_2} = \frac{E_{si}}{E_n}A_1 \qquad \ldots \quad \ldots \quad \ldots \quad (2)$$

which is exactly the same as would have been obtained with the same amplifier without feedback.

However, it is perhaps more legitimate to compare the feedback amplifier with a non-feedback amplifier, Fig. 2 (b), having the same overall gain $\alpha_1\alpha_2 = A/(1 + A\beta)$. In the case of this amplifier the signal-to-noise ratio at the output is given as

$$R_{NFB} = \frac{E_{si}\,\alpha_1\,\alpha_2}{E_n\,\alpha_2} = \frac{E_{si}\,\alpha_1}{E_n}$$

and comparing this with equation (2) we have

$$\frac{R_{FB}}{R_{NFB}} = \frac{A_1}{\alpha_1}$$

Thus, for noise originating in the first stage of the amplifier, we have $A_1 = \alpha_1$ and there is obviously no improvement by using feedback. If, however, we consider noise originating near the output stage of the amplifier such that $A_2 = \alpha_2$, then for the same output and input voltages the signal levels at every point in A_2 and α_2 are identical and the feedback case shows

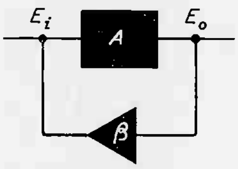


Fig. 1. *Feedback amplifier*

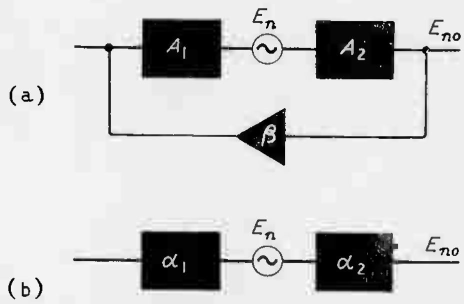


Fig. 2. *Effect of noise introduced in amplifier; (a) with feedback; (b) without feedback*

* *Department of Electrical Engineering, The University of Manchester.*

an improvement in signal-to-noise ratio by the factor

$$\frac{A_1}{\alpha_1} = (1 + A\beta)\frac{\alpha_2}{A_2} = (1 + A\beta)$$

Thus, provided $A_2 = \alpha_2$, we obtain compensation for noise introduced anywhere in A_2. In A_1, however, the signal levels are less than at any point in α_1, and the improvement in signal-to-noise ratio for noise originating in this part of the amplifier is only partial. The improvement decreases as we approach the input, and has already been shown to be zero at that point ; this results from the fact that the signal level at the input has also been reduced by a factor of $1/(1 + A\beta)$.

Thus, feedback is a useful means of combating troubles originating in the output stages of the amplifier. For example, in reducing the effect of hum resulting from the use of valves with directly-heated cathodes in the output stage. It should be noted, however, that even in this case, the same result could have been obtained without feedback by using the whole amplification ($A = A_1A_2$) and attenuating by a factor $1/(1+A\beta)$ after the amplifier. This would have increased the signal at the point of noise injection by a factor $(1 + A\beta)$ so that the output signal-to-noise ratio would have been the same as when employing feedback. Thus, even in this particular case, the same result could be obtained without feedback except in the case when for some other reason (e.g. linearity or power-handling capacity) the increased signal cannot be applied to the stage in which the noise originates.

The above considerations show that feedback is of little use in reducing the effect of shot or thermal noise originating in the input stages of the amplifier. In particular cases, however, the use of feedback may enable the input circuit to be designed in such a way as to reduce these effects. In fact, as will be shown later, in certain cases when the noise generated in the input resistor is the limiting factor an improvement in signal-to-noise ratio may be obtained by using feedback.

Alternative Method of Treatment

In problems concerning noise, it is often more convenient and instructive to refer all noise back to the input as an equivalent noise at that point. Applying this method to the case of Fig. 2, the noise generator E_n at the input of A_2 would be replaced by an equivalent generator E_n/A_1 at the input to A_1. This would then result in a noise output

$$E_{no} = \frac{E_n}{A_1}\frac{A}{1 + A\beta} = \frac{E_nA_2}{1 + A\beta}$$

which is identical to equation (1), and this method of treatment will be used further in this paper.

Noise Originating in the Input Circuit

The simplest arrangement for the input of an amplifier is shown in Fig. 3 (a). Any noise originating after the first valve or shot noise in the valve may be considered in terms of an equivalent noise generator in the grid circuit of the valve. The other source of noise is due to thermal agitation in the resistance R in the input circuit. This thermal noise in the input circuit is often the major source of noise, particularly in the case of high impedance, or current, amplifiers, and it is with this type of amplifier that the use of feedback enables the input circuit to be designed so as to obtain large improvements in signal-to-noise ratio.

Signal-to-Noise Ratio in High-Impedance Amplifiers Without Feedback[2,3].

The thermal noise generated in the resistance R is uniformly distributed over the frequency spectrum, and over a bandwidth df may be represented by a series-voltage generator having a mean square voltage given by $[v_n^2]_{mean} = 4RKTdf$, or by a parallel current generator $[i_n^2]_{mean} = \frac{4}{R}KTdf$, where K = Boltzmann's Const., and T is the temperature of the resistor (°K).

As the voltage produced by the input current I is proportional to the input resistor R, while that due to thermal noise is proportional to $\sqrt{R}$, it appears, at first sight, that for best results it is necessary to make R as large as possible. We have, however, neglected the fact that there are inevitable stray capacitances shunting the input resistor. The equivalent circuit of the amplifier should, therefore, be as shown in Fig. 3 (b).

Thus, although the signal and noise inputs to the system are as indicated above, the frequency response of the system is given by $E \propto I_\omega R/\sqrt{(1 + \omega^2C^2R^2)}$ as shown in Fig. 4. That is, it may be considered as flat up to $\omega CR = 1$ after which it drops off at 6 dB per octave.

If, therefore, R is made too large, the frequency response deteriorates and, in practice, the best arrangement is to make the input resistor as high as possible without infringing any frequency response requirements. Under such conditions, the mean square noise voltage appearing across the capacitor at an angular frequency ω is

$$\left[E_\omega^2\right]_{mean} = \frac{2KTR}{\pi}\frac{d\omega}{1 + R^2C^2\omega^2}$$

so that the total mean square voltage across the

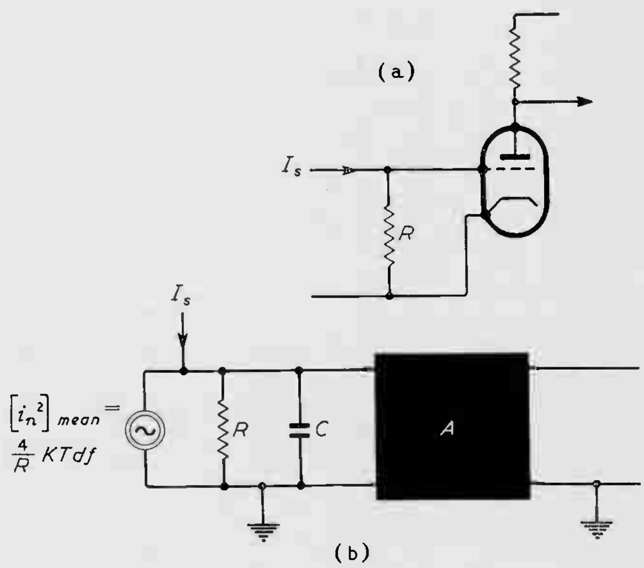


Fig. 3. *Effect of input circuit*

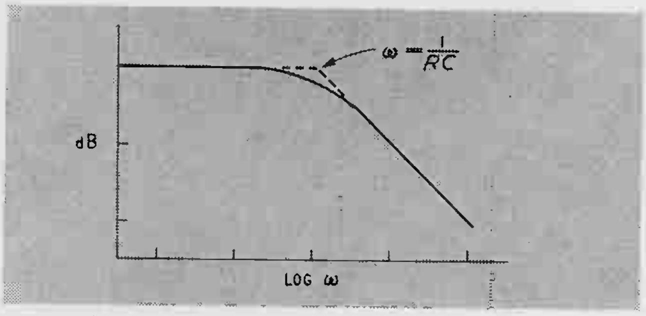


Fig. 4. *Frequency response of input circuit*

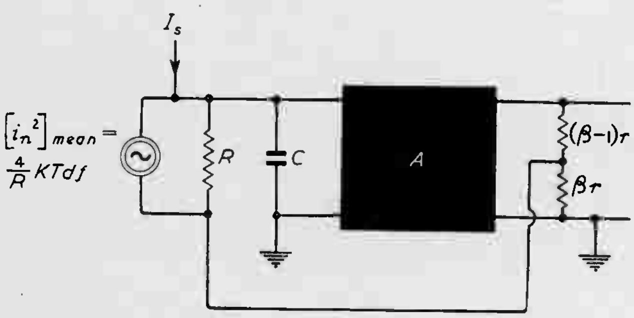


Fig. 5. *Effect of input circuit with feedback*

capacitor is

$$E^2 = \frac{2KTR}{\pi}\int_0^\infty \frac{d\omega}{1+\omega^2C^2R^2}$$
$$= \frac{2KTR}{\pi}\left[\frac{1}{CR}\tan^{-1}(\omega CR)\right]_0^\infty$$
$$= \frac{KT}{C} \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

Then, for a low-frequency input current I, the signal-to-noise ratio at the input, which is the same as that at the output provided no additional noise is produced in the amplifier, is seen to be $IR\sqrt{(C/KT)}$. For example, if a response up to 3 Mc/s is required and C is 10pF then R cannot exceed 5 kΩ for, although a higher value would improve the signal-to-noise ratio, it would not give the required bandwidth.

With the values mentioned above, a signal-to-noise ratio of unity would be obtained with an input current of $0{\cdot}003\mu$A.

The frequency response of the amplifier itself has not been considered above as we were dealing with the input circuit. However, provided we assume the amplifier has a flat response to an angular frequency $\Omega \gg 1/RC$ it will not affect the signal-to-noise ratio. When considering the amplifier with feedback we shall similarly assume that its response is such that the response of the whole system is determined by that of the input circuit.

Signal-to-Noise Ratio in High Impedance Amplifier with Feedback[3]

We will now consider the amplifier when negative feedback is employed, as indicated in Fig. 5. The attenuating resistors βr and $(\beta-1)r$ which are assumed to be $\ll R$ have been included for the sake of generality though normally the feedback resistor R would be connected directly to the output of the amplifier so that β is unity.

The output due to an input current of angular frequency ω is

$$\frac{IRA}{1+A\beta}\,\frac{1}{\sqrt{\left(1+\dfrac{\omega^2C^2R^2}{(1+A\beta)^2}\right)}}$$

that is, it is identical to that of the non-feedback amplifier with R replaced by $R/(1+A\beta)$. Considering the noise due to the resistor R, the total noise voltage across the capacitor at an angular frequency B is given by

$$E_\omega = \frac{\left(\sqrt{\left(\dfrac{2KTR}{\pi}d\omega\right)} - A\beta E\omega\right)\dfrac{1}{j\omega C}}{R+\dfrac{1}{j\omega C}}$$

whence

$$E_\omega = \frac{\sqrt{\left(\dfrac{2KTR}{\pi}\,d\omega\right)}}{1+A\beta+j\omega RC}$$

The total mean square voltage across the capacitor is thus

$$E^2 = \frac{2KTR}{\pi}\,\frac{1}{(1+A\beta)^2}\int_0^\Omega \frac{d\omega}{1+\left(\dfrac{R}{1+A\beta}\right)^2\omega^2C^2}$$
$$= \frac{2KTR}{\pi}\,\frac{1}{(1+A\beta)^2}\left[\frac{1}{\dfrac{R}{1+A}C}\tan^{-1}\left(\frac{\omega CR}{1+A\beta}\right)\right]_0^\Omega$$
$$= \frac{KT}{C}\,\frac{1}{1+A\beta} \qquad \left(\text{as } \Omega \gg \frac{1}{RC}\right)$$

so that the mean square noise voltage at the output is $KTA^2/C(1+A\beta)$ and for a low-frequency input I the signal-to-noise ratio at the output is

$$\frac{IRA}{(1+A\beta)}\sqrt{\left(\frac{(1+A\beta)\,C}{A^2\,KT}\right)} = IR\sqrt{\frac{C}{KT}}\,\frac{1}{\sqrt{(1+A\beta)}}$$

That is, the performance as regards signal-to-noise ratio is worse by a factor of $\sqrt{(1+A\beta)}$ when compared with the same amplifier without feedback. However, it should be remembered that, at the same time, the feedback has increased the bandwidth of the amplifier by a factor of $(1+A\beta)$. In order to obtain an amplifier with an identical frequency response to the non-feedback amplifier, the value of R may be increased to $R' = R(1+A\beta)$. The signal-to-noise ratio at the output is then

$$IR'\sqrt{\frac{C}{KT}}\,\frac{1}{\sqrt{(1+A\beta)}} = IR\sqrt{\frac{C}{KT}}\sqrt{(1+A\beta)}$$

which is better than that for the non-feedback by a factor of $\sqrt{(1+A\beta)}$.

Thus, it is seen that if a high-impedance amplifier with a specified bandwidth is required, and the noise in the input circuit is the limiting factor, a definite advantage is obtained by employing negative feedback. This is because the noise is generated in a resistor with a large physical value, whereas the frequency response depends on the modified value obtained by using negative feedback.

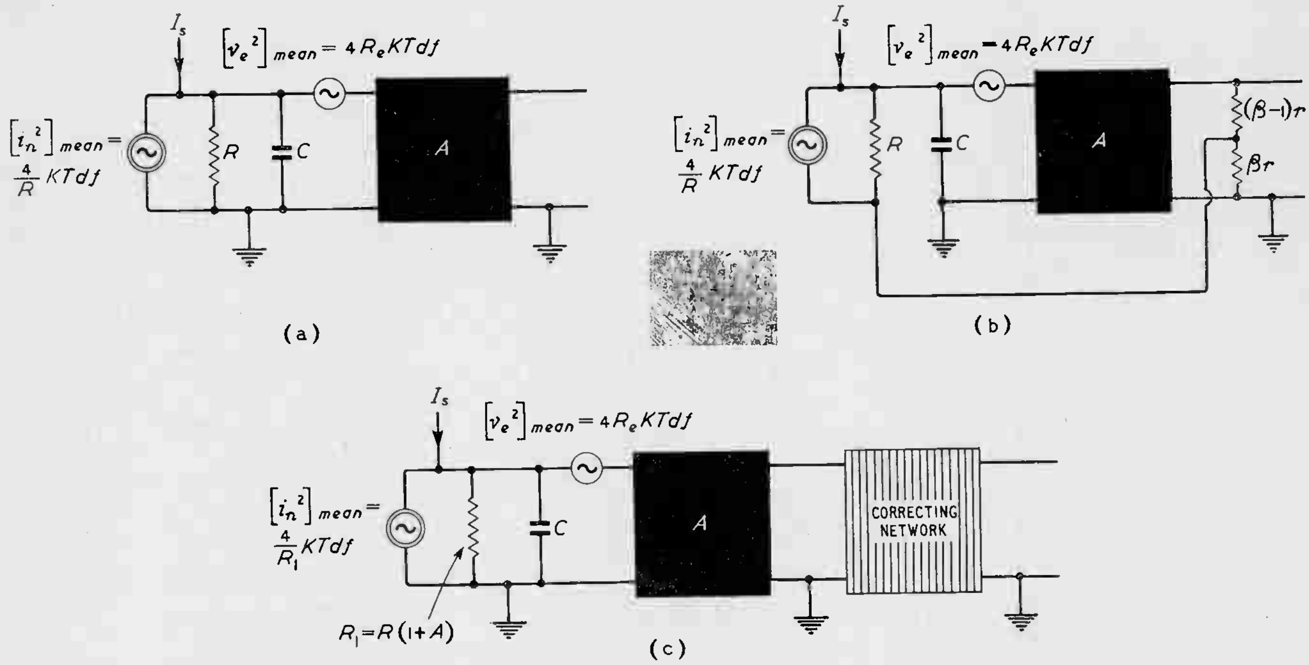


Fig. 6. *Effect of noise generated in amplifier; (a) without feedback; (b) with feedback; (c) with correcting network*

Effect of Noise Generated in the Amplifier

So far, in this case of a high impedance amplifier, we have only considered the noise due to thermal agitation in the input circuit and have neglected any noise generated in the rest of the amplifiers. The true random noise generated in the amplifier may be referred back to the input of the amplifier and treated as an equivalent voltage generator at the grid of the first valve having a mean square voltage given by $[v_{eq}{}^2]_{mean} = 4R_eKTdf$. We will now consider the two amplifiers [Figs. 6 (a) and 6 (b)] with equivalent responses. For the non-feedback amplifier [Fig. 6 (a)], the mean square noise output is

$$E^2 = A^2\frac{2KT}{\pi}\int_0^{\Omega}\left(\frac{R}{1+\omega^2C^2R^2} + R_e\right)d\omega$$

$$= A^2\left\{\frac{KT}{C} + \frac{2KT}{\pi}R_e\Omega\right\}\left(\text{as } \Omega \gg \frac{1}{RC}\right)$$

while in the case of the feedback amplifier [Fig. 6 (b)], we have

$$E_{\omega i} = \left\{\beta E_{\omega 0} + \sqrt{[v_n{}^2]_{mean}}\right\}\frac{1}{1+j\omega CR'} + \sqrt{[v_{eq}{}^2]_{mean}}$$

and $E_{\omega 0} = -A\,E_{\omega i}$

$$\therefore E_{\omega 0} = A\left\{\frac{\sqrt{[v_{eq}{}^2]_{mean}} + \sqrt{[v_n{}^2]_{mean}}\,\dfrac{1+j\omega CR'}{1}}{1 + A\beta\,\dfrac{1}{1+j\omega CR'}}\right\}$$

$$\text{So}\left[\overset{2}{E}_{\omega 0}\right]_{mean} = A^2\left\{\frac{[v_n{}^2]_{mean} + [v_{eq}{}^2]_{mean}\,(1+\omega^2C^2R'^2)}{(1+A\beta)^2 + \omega^2C^2R'^2}\right\}$$

(Since there is no correlation between $[v_e{}^2]_{mean}$ and $[v_n{}^2]_{mean}$ their product is zero.)

The total mean-square voltage appearing at the output is thus

$$E^2 = A^2\frac{2KT}{\pi}\int_0^{\Omega}\frac{\omega^2C^2R'^2R_e + R' + R_e}{(1+A\beta)^2 + \omega^2C^2R'^2}\,d\omega$$

$$= \frac{2A^2KT}{\pi}\left[\frac{R_e}{2}\log\left\{(1+A\beta)^2 + \omega^2C^2R'^2\right\} + \left\{\frac{R'+R_e}{(1+A\beta)\,R'C}\tan^{-1}\left(\frac{\omega CR'}{1+A\beta}\right)\right\}\right]_0^{\Omega}$$

$$= \frac{2A^2KT}{\pi}\left[\frac{R_e}{2}\log\left\{1 + \frac{\Omega^2C^2R'^2}{(1+A\beta)^2}\right\} + \frac{1}{1+A\beta}\left(1+\frac{R_e}{R'}\right)\frac{\pi}{2C}\right]$$

(as $\Omega \gg 1/RC$)

$$= A^2\left[\frac{KT}{C}\,\frac{1+R_e/R'}{1+A\beta} + \frac{R_eKT}{\pi}\log\left\{1 + \frac{\Omega^2C^2R'^2}{(1+A\beta)^2}\right\}\right]$$

By comparing this with equation (3) it is obvious that, provided the equivalent noise resistance of the amplifier is small compared with the input resistance R, then by employing feedback and increasing the input resistance to $R_1 = R(1 + A)$, there is still a large gain in signal-to-noise performance as the signal response has not been affected while the mean square noise voltage has been reduced by an amount

$$\frac{A^2KT}{C}\left\{\frac{RA\beta\,(1+A\beta) - R_e}{(1+A\beta)^2\;R} - \frac{R_eC}{\pi}\log\,(1+\Omega^2C^2R^2)\right\}$$

In practice, in a well-designed amplifier, R_e might be 1kΩ and as previously mentioned if C is 10pF and the required bandwidth is 3 Mc/s, R could be 5 kΩ. Thus as A could be large, the reduction in output noise due to feedback would not greatly differ from $\frac{A^2KT}{C} \cdot \frac{A}{1 + A\beta}$ which is the result when the amplifier is considered as noiseless.

The term containing $R_e\Omega$ in these equations should not be neglected for it illustrates the point that the mean-square output due to noise $[v_{eq}^2]_{mean}$ depends on Ω, the cut-off value of the amplifier excluding the input circuit. Therefore, although we require Ω to be sufficiently large, it should not be too great as this only increases the noise output without increasing the signal. Taking the above values for the constants and making Ω correspond to 10 Mc/s with $A = 1\,000$, and $\beta = 1$, the results for the equivalent r.m.s. input noise currents are shown in Table 1.

Table 1

	Total Noise (amps)	Thermal Noise in Input Circuit (amps)	Shot and Subsequent Noise
No feedback ..	4×10^{-9}	4×10^{-9}	$3{\cdot}6 \times 10^{-11}$
With feedback	$1{\cdot}3 \times 10^{-10}$	$1{\cdot}3 \times 10^{-10}$	$8{\cdot}1 \times 10^{-13}$

Alternative Method of Improving Signal-to-Noise Ratio

It is important to note that the improvement in signal-to-noise ratio has been obtained when using feedback because the actual value of the input resistor is large. Neglecting all noise except that in the input circuit, a similar result could in theory be obtained by using the large-valued input resistor and by interposing a correcting network with a transfer function of the form $\sqrt{[(1 + A\beta)^2 \omega^2C^2R^2 + 1/(\omega^2C^2R^2 + 1)]}$ after the amplifier to obtain the desired overall frequency response. (Fig. 7.)

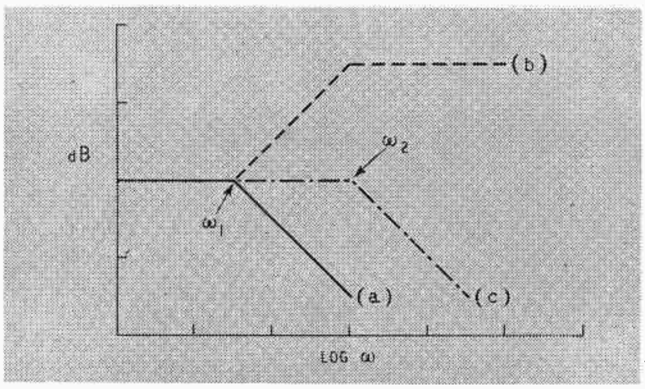


Fig. 7. *Frequency responses with correcting network; (a) input circuit; (b) correcting network; (c) overall*

With this system illustrated in Fig. 6 (c) expressions for the output signal and noise are identical with those for the feedback amplifier when only noise originating in the input circuit is considered. However, when considering noise generated subsequent to the input stage this system is seen to be inferior, for, owing to the poor frequency response of the input circuit, the signal level at the grid of the first valve is so low for angular frequencies in the region between ω_1 and ω_2 (Fig. 7) that noise generated in this range is of great importance. In fact, for frequencies in this range, there is a large weighting factor in favour of internally generated noise.

The problem may perhaps be viewed more clearly if in the two cases the noise originating subsequent to the input of the amplifier is referred back not as an equivalent voltage at the input of the amplifier, but as an equivalent input current. Then, in the case of the feedback amplifier with an equivalent noise voltage $\sqrt{[v_{eq}^2]_{mean}}$ on the grid, the equivalent input noise current is given by

$$[I^2_\omega]_{mean} = \frac{[v_{eq}^2]_{mean}\{1 + (1+A\beta)^2 \omega^2C^2R^2\}}{(1 + A\beta)^2 R^2} \cdot \frac{R^*}{1 + \omega^2C^2R^2}$$

while in the case of the amplifier with compensating network for an equivalent voltage $\sqrt{[v_{eq}^2]_{mean}}$, the equivalent current is given by

$$[I^2_\omega]_{mean} = \frac{[v_{eq}^2]_{mean}\{(1 + A\beta)^2 \omega^2C^2R^2 + 1\}}{(1+A\beta)^2 R^2}$$

that is, for the range over which compensation is occurring, the equivalent fluctuating current is much greater with the system employing compensation than when using feedback.

Thus for applications requiring large bandwidths, when the equivalent noise of the amplifier becomes of importance compared with that generated in the input resistor, the feedback system is inherently superior to that employing compensation. For lower bandwidths there is no inherent advantage in the feedback system from considerations concerning random noise though, for other reasons, it is usually the more convenient and desirable system.

Conclusion

From the above discussion it is evident that the use of negative feedback can improve the signal-to-noise ratio at the output of an amplifier in two particular cases.

First, if the noise is generated in the later stages of the amplifier an improvement in signal-to-noise ratio can be obtained, but the same result would also be obtained if it were permissible to use the same amplifier without feedback so that there would be a larger signal voltage at the point of origin of the noise.

Of more importance is the case of a high-impedance amplifier, especially when a large bandwidth is required. An example of this is the pick-up amplifier of a television camera where the input is a small current and a bandwidth of several megacycles may be required. In this case the use of feedback enables a high-valued input resistor to be used with its attendant low noise current while keeping the input resistance of the amplifier low and thus maintaining the required bandwidth.

REFERENCES

[1] H. W. Bode, "Network Analysis and Feedback Amplifier Design", Van Nostrand, New York, 1945, pp. 33-35.

[2] I. L. P. James, "Fluctuation Noise in Television-Camera Head Amplifiers", *Proc. Instn elect. Engrs.*, Pt. III, 1952, Vol. 99, p. 796.

[3] K. Kandiah and D. E. Brown, "High Gain D.C. Amplifiers", *Proc. Instn elect. Engrs*, Pt. II, 1952, Vol. 99, p. 314.

The Instruments, Automation and Electronics Exhibition

Although there was a certain amount of overlap between this and the Physical Society's Exhibition, the impression made by the I.E.A. was radically different. Gone was the aura of happy improvisation, redolent of boffins and cups of tea in the lab., which surrounded so many of the Physical Society's exhibits. Instead, one looked at impersonal glossy cabinets, designed for appearance, convenience, efficiency and, above all, reliability ; at mechanical intricacies, fashioned from heavy brass and high-tensile alloys ; at big valves and motors which were obviously anything but laboratory toys.

This was just as it should be. If we are to have a host of exhibitions, they ought at least to be different from one another. The Physical Society's is about research, and the measurement that goes with research. The I.E.A. was about control, hence the bewildering array of specialized industrial control equipment, together with instruments for performing measurements of quantities of a far from fundamental character—everything, in fact, from hydraulic servo-systems to photo-extinction sedimentometers.

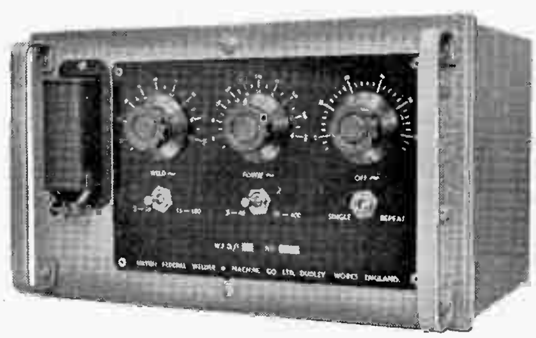
The I.E.A. was, very largely, a selling exhibition and it was good to see so much attention paid to the external appearance of equipment as well as to the soundness of its engineering design. Another factor which received due emphasis was speed. Such things as high-speed counting and batching are, of course, commonplace, but it is now possible to perform such operations as a complete spectrographic analysis of an aluminium alloy automatically in two or three minutes, or to carry out endless sequences of titrations and record the results without human aid.

The performance of the human mechanism under various conditions is being investigated by a branch of the Ministry of Supply which, under the homely title of Clothing and Stores Experimental Establishment, showed what happened if you shake somebody hard enough. One learned, for example, that "Reduction in vision was maximal between 25–40 and 60–90 c/s . . . due to resonance of the eyeball and surrounding structure ". The particular victim who was being vibrated when we visited the exhibition did not appear to be worried.

However, it was something of a relief to turn to the D.S.I.R. stand and find apparatus which dealt only with inanimate things. It contained a score of instruments, for the most part developed by allied research associations in particular industries. Consequently, the instruments shown were down-to-earth jobs developed to meet specific industrial needs. Simplicity was one of the keynotes. For example, a device for measuring the tension on a running thread contains nothing more complicated than a selenium cell and a microammeter. A light-weight feeler arm deflects the thread by a small amount proportional to the tension, and moves an opaque vane which shuts off some of the light to the photocell, giving a meter deflection proportional to tension. This instrument was shown by the British Jute Trade Research Association, who also had a device for measuring the moisture content of textile packages. The capacitance of a metal rod to earth is changed when it is inserted into a package. This detunes an oscillator, and the frequency change, which is proportional to humidity content for a given textile, is measured by zero-beating a second oscillator.

British Rayon Research Association showed sensitive pressure-transducers designed for measuring the radial pressure on a bobbin with superimposed layers of thread, and a 'lustremeter' for investigating small localized changes of lustre which are associated with a particular fault in cloth.

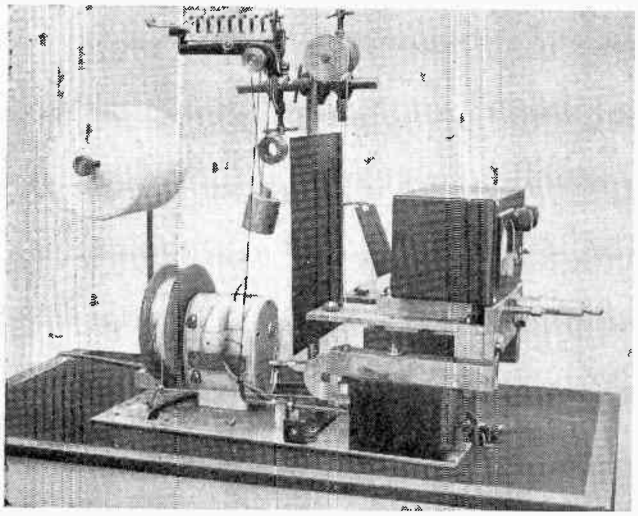
Dynamometer for extensile testing. (*Research Association of British Rubber Manufacturers*)



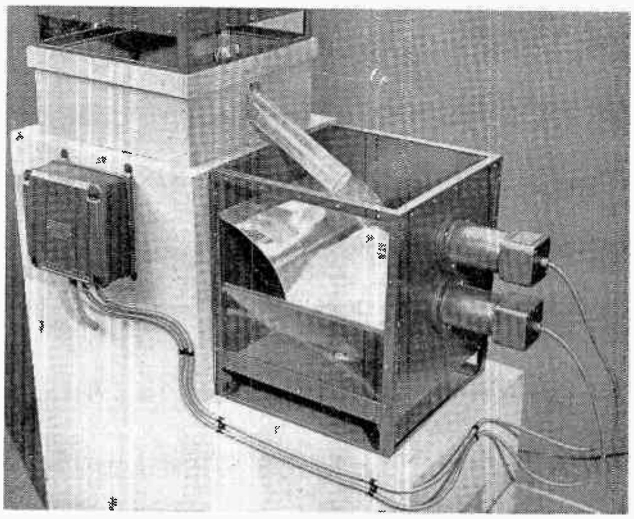
Sequence-weld timer. (*British Federal Welder & Machine Co.*)

An electronic tensile tester (British Rubber Manufacturers' Research Association) automatically tested rubber samples. A steel 'proof ring', which is deformed linearly by increasing strain, is coupled to a conventional displacement transducer, the output of which, suitably amplified and detected, is continuously recorded. Automatic range-changing is embodied in the recorder. At the same time, a simple electro-mechanical extensometer produces calibration markings on the record for fixed increments of length of part of the test specimen. A specimen may be tested to destruction in about 20 seconds.

Of more general interest (Fig. 1) was a semi-micro vacuum balance (British Coke Research Association) for use in measuring magnetic susceptibility. The problem is to measure



Equipment for yarn tension measurement. (British Jute Trade Research Association)



Transistor-operated level controller in action. (Lancashire Dynamo Electronic Products)

the small changes in apparent weight of a relatively heavy specimen when the latter is subject to a magnetic field, and the accuracy actually obtained is 5 microgrammes. When the beam of the balance tilts, a simple optical system unbalances the light falling on a pair of photocells. The resulting out-of-balance output is amplified and used to energize an electro-magnet which tends to bring the system back into balance, the current required to do so being a measure of the change in weight. If necessary, the instrument can be operated in an evacuated chamber.

The commercial exhibits included a host of conventional items, such as process timers, photocell-operated relays and counters. The emphasis here was on simplicity, reliability and economy, the last figuring in many other parts of the highly-competitive industrial instrumentation field. The tendency for 'heavy' engineers to fight shy of valves and stick to something more solid made itself felt in the shape of magnetic amplifiers in equipment where one might have expected valves. Metropolitan-Vickers, for example, had a four-stage magnetic timer of the mains cycle-counting type. A step towards automation was made in the sequence-weld timers shown by British Federal. These are switched on by a pressure-operated switch when the welding electrodes have made a good contact with the work, then the welding current is allowed to flow for a predetermined interval, then the current is switched off but the electrode pressure kept up for a further 'forge' period and, finally, there is an 'off' period to enable the work to be moved to the next position. Nagard showed a range of timers with a timing accuracy of $\pm$ 1 per cent.

Time-saving was also a feature of the Magna-Gage signal light indicator, a device which enabled an array of measuring transducers to be switched in sequence to a detector giving a measure of the magnitude and sense of the difference in dimension of a standard part from the part under test. The instrument can be set to predetermined tolerances and a good/bad indication given at each reading, so that inspection of a part can be effected rapidly and accurately.

Transistors are beginning to make their appearance in those types of industrial equipment in which their temperature limitations are not prohibitive. An extremely compact capacitance-operated level control using transistors and a printed circuit was demonstrated by Lancashire Dynamo. This contained a single stable oscillator, the effect of increased probe capacitance being to reduce the amplitude of oscillation and operate a relay. Since the unit works from a 12-V low-current supply, there are advantages in situations where there is a risk of fire.

A gamma-ray detector for similar applications also employed a printed circuit (Isotope Developments). An advantage of this kind of detector is that it is quite feasible to detect changes in the level of the contents of, say, a metal hopper without

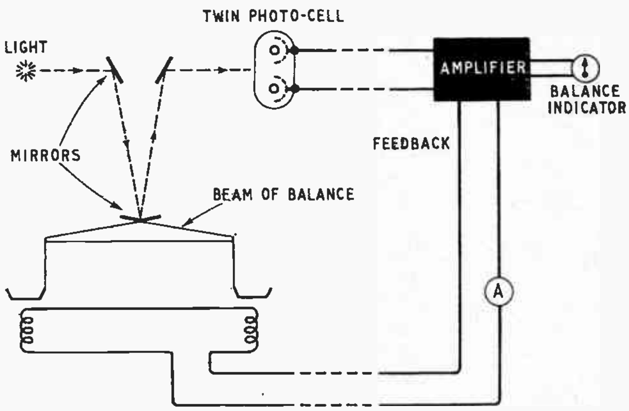


Fig. 1. *Diagram of semi-micro vacuum balance. (British Coke Research Association)*

cutting holes for electrodes, fitting floats and so forth, as is necessary with most other methods.

An example of the way in which the need for new industrial electronic equipment arises is illustrated by the presence at the exhibition of a number of photo-electric devices for measuring or recording the density of smoke in factory chimneys. The reason for their existence is the Clean Air Bill, which lays down limits to the amount of air pollution permissible. In some cases, a simple alarm giving warning of excessive smoke is all that is needed, while in others continuous recording of smoke density is required. Lancashire Dynamo showed a basic unit which meets both the relevant British Standard for a simple alarm and, with the addition of a recorder, that for a more comprehensive installation. Smoke-density equipment has to be calibrated using real smoke of standard density, which may not always be available. A useful adjunct to the equipment, therefore, is a calibrated slide which can be set to give a known obscuration.

Among the more conventional instruments were a number of pulse generators giving two or more output pulses with variable time interval. Such instruments are of use for the calibration of ratemeters. Fleming Radio had a crystal-controlled double-pulse generator, a feature of which is that the width of each pulse in a pair can be varied independently. A pre-pulse is also available for triggering oscilloscopes, etc. Nagard showed a generator with a high maximum p.r.f. (2·5 Mc/s) which delivered a main pulse preceded by a pre-pulse, the time interval between the two being variable between 0·2 μsec and 2 sec. Parts of an elaborate equipment for pulse-testing computer memory elements were shown by A. E. Cawkell. The complete instrument delivers groups of ten fast pulses with variable spacing.

Oscilloscopes were not strongly featured at the exhibition, but Solartron showed a new dual-trace instrument in which two traces are obtained from a single-gun tube by a beam-switch which either separates alternate sweeps or is operated by an internal 100-kc/s source. A kit of parts for a double-beam oscilloscope was shown by Cossor Instruments. A useful adjunct to a double-beam instrument is the B.T-H. 'electronic time-base ruler'. This is a time-interval marker based on a 100-kc/s crystal oscillator. Every fifth pulse is doubled in amplitude, while that of every tenth pulse is tripled, to provide a display resembling the markings of a ruler. The instrument uses transistors and is operated from dry batteries.

The need for quick tolerance-testing of components used in large-scale production was met by variations on conventional measuring instruments. Cintel, for example, showed a 'tolerance resistor bridge' catering for seven tolerance values between $\pm 1\%$ and $\pm 25\%$, and Advance showed a Q comparator. The latter firm also had a new type of attenuator for frequencies up to 1000 Mc/s ($\pm$ 1 dB) in which coaxially-constructed resistive pads are connected in turn between coaxial connectors as the control knob is rotated. A pair of step attenuators for use up to about 400 Mc/s was shown by Hatfield Instruments. One attenuator has ten steps of 10 dB, and the other ten steps of 1 dB, giving a total of 110 dB in 1-dB steps. The accuracy quoted is $\pm$ 1 dB at 100 Mc/s, and $\pm$ 2 dB at 300 Mc/s. Precision fixed attenuators ($\pm$ 0·3 dB at 1000 Mc/s) were also shown.

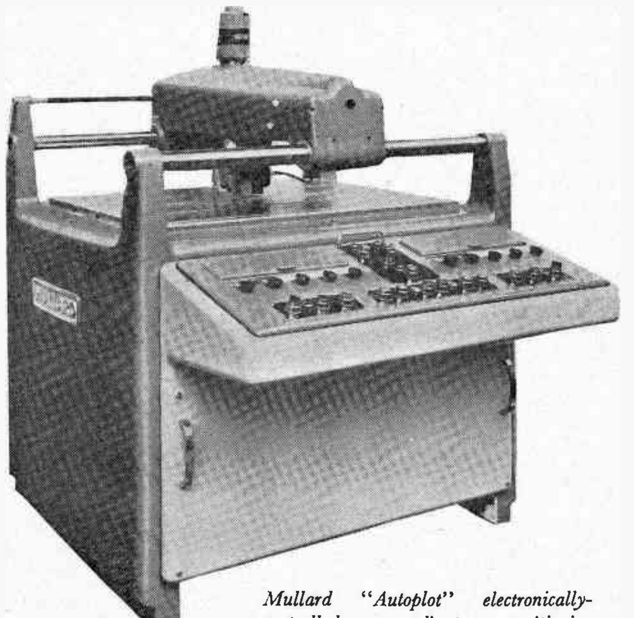
Precise standards of frequency were demonstrated by several firms. Airmec, for instance, have 100-kc/s crystal oscillators with day-to-day stabilities of 1 part in 10^{10}. An alternative is to utilize a standard-frequency radio transmission. The B.B.C.'s 200-kc/s Droitwich transmitter though not, strictly speaking, a standard-frequency source, is known to be stable and is convenient for the purpose. Racal showed a straight receiver for 200 kc/s, which embodies sharp filters and limiters to purge the carrier of the unwanted sidebands.

New valve and transistor testers included both simple and elaborate instruments. A transistor tester shown by Bonochord gives quick but accurate checks of collector leakage, current gain and noise, while a more elaborate one by Microcell Electronics enables operating characteristics to be measured in various circuit configurations. Cossor showed a pulse-operating valve analyser for obtaining families of valve characteristic curves. Since the duty ratio employed is small, valve performance in the positive-grid region can be investigated.

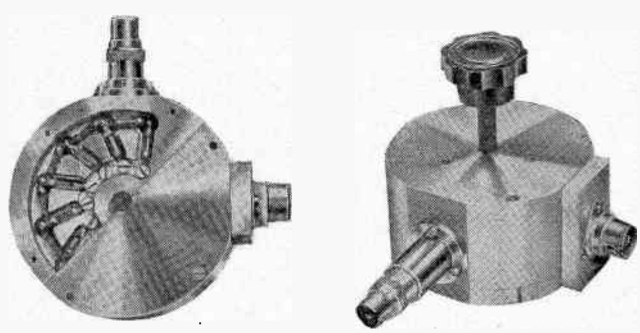
In addition to the investigation of the effects of vibration on human beings demonstrated by the Ministry of Supply, there were many equipments on show for vibration testing in industry. E.M.I., for example, showed with the aid of stroboscopes what happens to a typical piece of electronic equipment when subject to violent vibration. Large low-frequency power amplifiers (one with a 10-kW output) were shown by several firms, including Savage, Solartron, and A. E. Cawkell.

Particle counting and sizing is an important operation in the investigation of paints and pigments, air pollution by dust, fuel sprays, etc., and several equipments for the purpose were shown. Those by Mullard and Cintel are virtually all-electronic, the object of interest being scanned by a flying-spot tube tracing out a television-type raster. An important part of such a counter is a line-to-line memory, the function of which is to prevent large particles, which intercept successive scanning lines, from being counted twice. The latest Mullard instrument employs a mercury-filled delay line with quartz-crystal transducers for this purpose. In another particle counter, by Casella Electronics, scanning is effected by a mechanical arrangement in which a slit allows part of the light from an optical system to pass. The amount of obscuration of the slit by a particle gives an indication of the latter's size, and the number of obscurations depends on the number of particles. The output end of the Casella system employs photocells and electronic counters. This, and the Cintel machine, are arranged to scan microscope slides, while the Mullard counter scans film records of particle samples.

Chemical analysis is such an important industrial operation that it was not surprising to see a number of devices for speedy and, in some cases, automatic analysis. The automatic titrimeter shown by Electronic Instruments was an intriguing affair of flasks, beakers, taps and burettes. Samples of test liquid were taken and a neutralizing agent added until a predetermined pH was reached, whereupon a photocell follower device explored the level of unused reagent and signalled an appropriate reading to a recorder, this process



Mullard "Autoplot" electronically-controlled co-ordinate positioning machine



Variable r.f. step attenuator. (Hatfield Instruments)

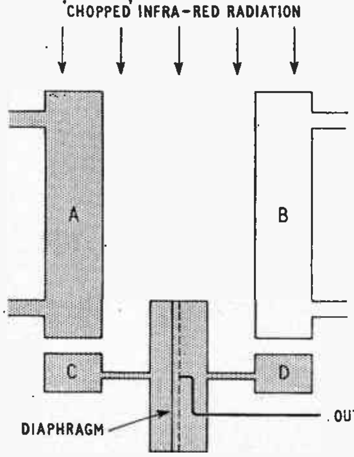
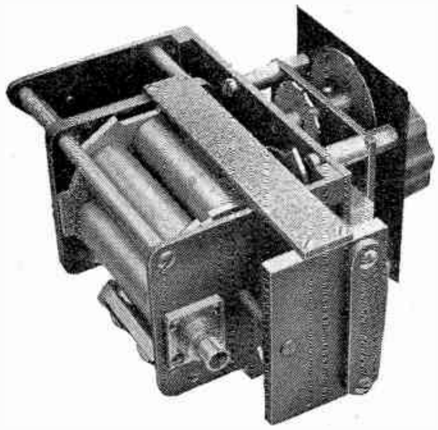
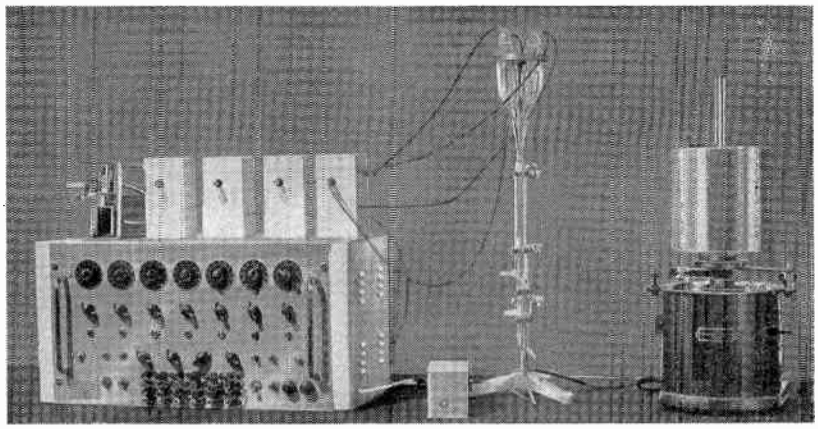


Fig. 2. *Gas detection apparatus. Tube A contains air to be tested, tube B pure air, and C and D samples of the gas of interest. (Infra Red Development Co. Ltd.)*



Turret-type attenuator for frequencies up to 1000 *Mc/s.* (*Advance Components*)



Biological assay apparatus for analysis of drugs. (*Casella Electronics*)

repeating itself *ad infinitum*. Another automatic equipment, by Casella, tested drugs by applying them to a sample of tissue and then recording the latter's contractions. Fantastically small drug samples (about 0·1 microgramme) yield results accurate to $\pm$ 3 per cent

Spectrochemical analysis was represented by some superbly engineered Hilger direct-reading spectrographs. The electronics in these, as in so much of the electro-chemical apparatus, was at the output end, photomultipliers being used to measure the outputs of exit slits 'tuned' to individual absorption lines. One instrument had thirty such channels. An interesting system is employed for handling the output information. Each photomultiplier output current charges a low-leakage capacitor. At the end of an exposure, the capacitor voltage is applied to a valve, together with a sawtooth voltage. The valve continues to give an output signal until the sawtooth voltage equals the capacitor voltage. During this period, a modulator is switched on by the valve and delivers a train of output pulses with a crystal-controlled recurrence frequency. These are counted by dekatrons and recorded on a printing device. The accuracy claimed for the system, which is really a quantizer or analogue-to-digital converter, is 1 part in 8,000.

A neat dodge employed in an instrument for recording the concentration of a single gas (Infra-Red Development Company) enables a prism or diffracting grating to be dispensed with. The essentials are shown in Fig. 2. The object of the exercise is to compare the concentration of the gas in a sample of air in tube A with the normal concentration in air. Accordingly, a sample of normal air is included (in tube B). Chopped infra-red radiation is passed through both, and the portion of this which is not absorbed reaches chambers C or D, which are filled with a pure sample of the gas to be measured. Some of the radiation is absorbed by the gas, with a resultant temperature-rise. If C and D get equal doses of radiation, their temperatures are equal and, if not, the temperature differential causes a diaphragm between C and D to move. The diaphragm is part of a charged capacitor, the voltage across which changes in sympathy, giving an output which is amplified and detected. Now, the gas in C and D can only absorb radiation of certain characteristic wavelengths. If some of the gas enters A, the available radiation at C is reduced and the instrument gives an output. But if some other gas enters A, and absorbs energy at other spectral frequencies, C will not be affected. It therefore behaves like a filter or like a spectrometer exit slit. As little as 3 parts per million of the wanted gas can be detected.

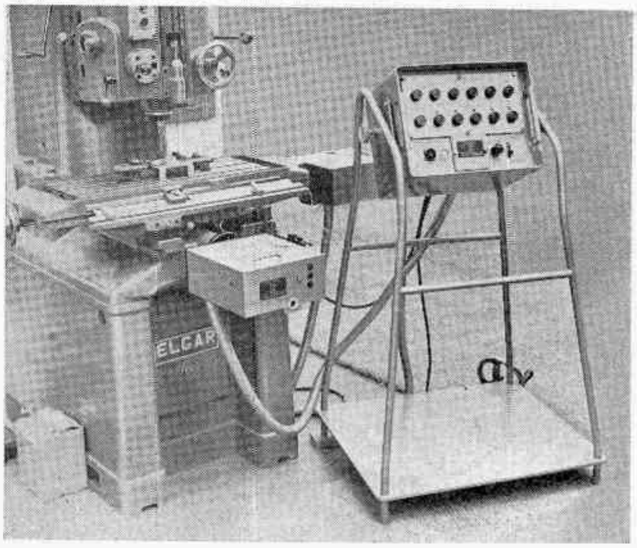
Other gas leak detectors included a mass spectrometer (Metropolitan-Vickers) capable of detecting leaks in vacuum systems of 5×10^{-7} litres per second at 10^{-3} mm Hg., and the 'Hogas' detector shown by Wright Alexander & Co. which incorporated a special 'catalyst' of German origin and unknown composition, the temperature of which increases on the arrival of a foreign gas (e.g., 0·01 per cent CO). The rise is detected by a thermistor bridge.

Several firms, including Pye, Metropolitan-Vickers, and Solartron, exhibited equipment for gas-liquid chromatography. This is a relatively new and very simple technique for analysing volatile organic substances such as the alcohols and fatty acids. The apparatus consists of a long tube or column packed with an inert substance soaked in a suitable solvent. A sample of the substance to be analysed is introduced at one end, and the resultant vapour, which consists of a mixture of the component parts, is carried down the column by an inert carrier gas. The action of the solvent in the column is to 'hold' different components for different lengths of time, so that they emerge in succession. All that is required to complete the apparatus is some means of determining which is which, and this can be done by measuring the thermal conductivity of the column output, each component having a characteristic conductivity. The process involves a suitable cell incorporating a resistance thermometer whose output is amplified and recorded.

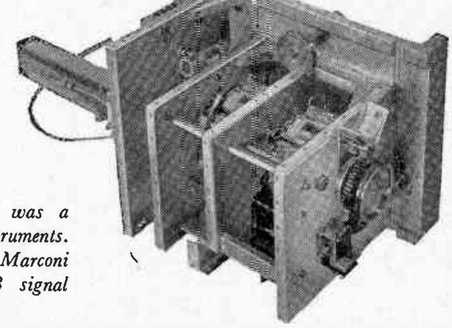
A number of computers, both analogue and digital, were shown. These were mostly small or medium-sized general-purpose machines. Printed circuits are widely employed in computers, often in the form of plug-in circuit panels. Transistors were employed in the Metrovick 950 machine's arithmetic unit. Among computer-like devices was the Southern Instruments Deciplex calculator, an electronic equivalent of the normal desk calculator. This machine works in decimal numbers and it is claimed that much higher speeds are possible than those obtained with the mechanical type. Another time-saving machine shown by the same company was a manually-operated data reduction equipment for handling records (of 'process variables', etc.) and producing corresponding digital records. For example, digital read-out is obtained by the operator positioning a cursor over the required point on a curve. A code-plate and brushes actuate a typewriter, tape punch or similar device. Another device gives an analogue read-out in the form of a voltage and this can, if necessary, be passed to a function generator before being converted to digital form.

Although magnetic drums are used in the main stores of many computers, multi-channel tape recording is a possible alternative where a very large storage capacity is required. Pye showed an 8-channel machine with a capacity of 1½ million bits per channel on a 2,400-ft. tape.

If automation as applied to industrial production has not featured prominently so far in this account of the exhibition it is because, on the one hand, there was not very much to be seen and, on the other, that it was not all electronic. There were, however, one or two complete equipments and some interesting pointers to future developments. Indeed, the main reason for the paucity of automation exhibits was that it is often physically impracticable (or very expensive) to demon-



Jig-borer with automatic positioning by lead-screw control. (Ekco Electronics)



Mechanical precision was a feature of many instruments. The r.f. box of the Marconi Instruments TF801B signal generator

strate a complete production process. Several firms put on interesting animated displays designed to give the essential information about automatic processes such as oil refinery and reactor fuel-rod control.

An electronic photographic printer (Cintel) is designed to correct unevenly-exposed negatives such as may be produced in aerial surveys. Contact prints are made by using a flying-spot tube as the light source. The density of the negative is measured continuously by a photocell and an appropriate voltage applied to the flying-spot tube so as to control the brightness to obtain the best print.

Mullard showed the 'Autoplot', a machine for drilling, marking-out, plotting, and similar operations on sheet material of all kinds. It consists of a work-table, tool carriage and gantry, and electronic circuits. The working area is 30 in. × 20 in., and the tool head is positioned automatically once the desired co-ordinates have been set up by the operator on dials. The accuracy claimed is 0·001 in. in 6 inches and 0·002 in. over the whole working area.

A hydraulic system of automatic copying for centre lathes was shown by Metropolitan-Vickers, and an unconventional machine-tool control system by Ekco Electronics. The unconventional feature is the positioning of the tool by means of the lead-screws instead of by a linear measurement system. The usual objection to this, that imperfect lead-screws can give incorrect positioning, is met by inserting corrective data in the control equipment.

The essentials of a most interesting machine tool control system were demonstrated by Laurence, Scott & Electromotors. Unlike conventional systems, this employs analogue devices, though the very high accuracy of 1 part in 180,000 is envisaged (0·0002 in. in 36 in.). The system is based on two elements—very accurate transformers ('toroidal voltage dividers') and precision resolvers. In a linear measurement system, tappings on a voltage divider provide accurately-defined voltages at a series of fixed contacts, equally-spaced, parallel to one side of a machine tool table. If now a contact which moves with the table makes with one of the fixed contacts, it will receive a voltage accurately proportional to the table's position. There is a limit to the number of tappings which can be so provided, and a means of interpolation is necessary. This is done by a resolver. The accuracy of voltage-divider tappings can approach 1 in 10^6, and that of resolvers exceed 1 in 20,000. Angular position may also be measured accurately, and function generators may also be effected using the basic units.

Among the smaller components were some useful transducers, including a pneumatic-electrical converter (Metropolitan-Vickers) and a very sensitive linear displacement pickoff (Sperry), capable of an output of several volts for a displacement of 0·025 in.

A new type of relay was shown by Smith's Industrial Instruments. This is for voltage or current control, the operating voltage or current required being constant within 1 per cent. Reference to Fig. 3. shows that the device is not unlike a moving-coil loudspeaker. The chief difference is that two auxiliary pole-pieces are provided. If there is no coil current, these attract the soft-iron armature which takes up the position shown. The field produced by the coil current opposes that of the auxiliary pole-pieces, tending to move the armature to the right. Once the armature begins to leave the gap between the auxiliary pole-pieces, a snap-action operation results. The operating power required is small (30 mW) and the contact pressure is relatively high.

Transistor-operated relays were shown by several firms, and a phototransistor/magnetic amplifier combination by Metropolitan-Vickers.

A useful new material for printed circuits, shown by Millet, Levens is 'Miltronite', which is sheet aluminium with laminate and copper coatings, as shown in Fig. 4. The material enables the wiring of a piece of equipment to be done on the back of a panel. The front of the panel is suitable for engraving dials and lettering, since it consists of a white layer covered by a black layer. The latter is removed in the engraving process, leaving white lettering showing through.

Among the valves on show were a sub-miniature cold-cathode trigger tube for computers, and another for direct operation from 250 V a.c. mains (Mullard), some new valves for r.f. heating (G.E.C., English Electric), and small high-current silicon junction power rectifiers (S.T.C.).

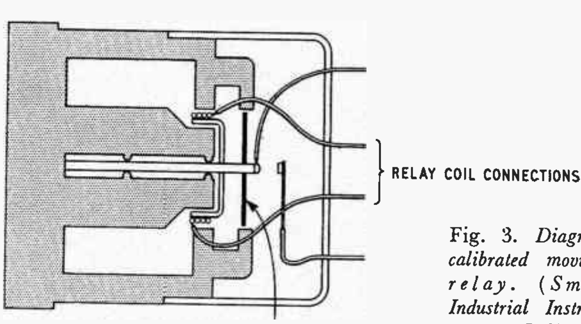


Fig. 3. *Diagram of calibrated moving-coil relay. (Smith's Industrial Instruments Ltd.)*

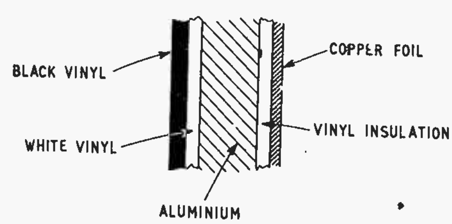


Fig. 4. *Cross-section through a sheet of "Miltronite" a new material for printed circuits. (Millett, Levens [Instruments & Engineering] Ltd.)*

Some Matrix Theorems

POWERS AND CONTINUED PRODUCTS OF 2 × 2 MATRICES

By W. Proctor Wilson, C.B.E., B.Sc.(Eng.), M.I.E.E.*

The use of matrix algebra in network problems has become widespread in recent years. In particular, the transmission matrix (known also as the transfer matrix, or the A matrix†) is of particular value, since it describes the relation between the input and output voltages and currents of a 4-pole according to the expression

$$\left.\begin{aligned} V_r &= a_{11}V_{r+1} + a_{12}I_{r+1} \\ I_r &= a_{21}V_{r+1} + a_{22}I_{r+1} \end{aligned}\right\} \quad .. \quad .. \quad \text{(i)}$$

In matrix form (i) assumes the well-known expression

$$\begin{bmatrix} V_r \\ I_r \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} V_{r+1} \\ I_{r+1} \end{bmatrix} \quad .. \quad .. \quad \text{(ii)}$$

The matrix $[a] = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$ is the transmission matrix which characterizes the network corresponding to (i) and (ii). The sign convention is that shown in Fig. 1.

It is well known that the transmission matrix of a composite 4-pole consisting of a number (say n) of simpler 4-poles connected in tandem is equal to the product of the transmission matrices of the component networks. In matrix notation

$$[a] = [a]_1 \cdot [a]_2 \ldots \ldots [a]_n = \prod_{s=1}^{n} \left\{ [a]_s \right\} \quad \text{(iii)}$$

where $[a]$ is the transmission matrix of the composite structure

$[a]_1, [a]_2, \ldots [a]_n$ are the transmission matrices of the component structures.

The connection of the networks is shown diagrammatically in Fig. 2, with the sign convention used.

In the case of tandem connection of n repeated 4-poles (i.e., iterated networks) of transmission matrix $[a]$, the continued product (iii) becomes a matrix which is $[a]$ raised to the power n. Other special cases described later correspond with particular continued products derived in this paper.

The theorems (expressed as matrix relations) described are all derived by induction, and require only the use of the rules for matrix multiplication. In particular, the theorem relating to the nth power of a matrix (power theorem) is believed to be new. It is derived without formal or explicit study of the latent roots of the matrix.

* *Research Department, British Broadcasting Corporation.*

† Derived from the notation of Strecker and Feldtkeller, *Electrische Nachrichtentechnik* (*E.N.T.*), 1929, Vol. VI, p. 93.

Power Theorem

Consider the square (non-singular) matrix

$$[A] = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}, \text{ of determinant } |A| \quad .. \quad \text{(1)}$$

Alternatively we may write

$$[A] = |A|^{\frac{1}{2}}[a] = |A|^{\frac{1}{2}} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \quad .. \quad .. \quad \text{(2)}$$

where $a_{ij} = \dfrac{A_{ij}}{|A|^{\frac{1}{2}}}$, and consequently $|a| = 1$.

We now express the a_{ij} of $[a]$ in terms of three parameters u, v, μ. We write

$$\left.\begin{aligned} \cosh u &= \tfrac{1}{2}(a_{11} + a_{22}) \\ \cosh^2 v &= \left\{ \tfrac{1}{4}(a_{11} + a_{22})^2 - 1 \right\} / a_{12}a_{21} \\ &= \left\{ \sinh^2 u \right\} / a_{12}a_{21} \\ \mu^2 &= a_{12}/a_{21} \end{aligned}\right\} \quad \text{(3a)}$$

from which may be derived the relations for the a_{ij}

$$\left.\begin{aligned} a_{11} &= \frac{\cosh (u+v)}{\cosh v}, & a_{12} &= \mu \frac{\sinh u}{\cosh v} \\ a_{21} &= \frac{1}{\mu} \frac{\sinh u}{\cosh v}, & a_{22} &= \frac{\cosh (u-v)}{\cosh v} \end{aligned}\right\} \quad \text{(3b)}$$

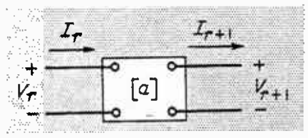


Fig. 1. *Sign convention adopted in definition of transmission matrix*

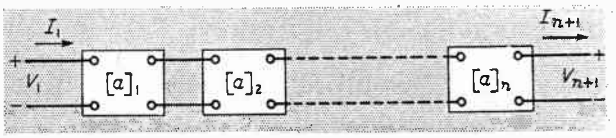


Fig. 2. *Connection of 4-poles in tandem, with sign convention adopted*

The theorem relating to powers of $[a]$ may now be expressed as follows:

$$[a]^n = \begin{bmatrix} \dfrac{\cosh (u+v)}{\cosh v} & \mu \dfrac{\sinh u}{\cosh v} \\ \dfrac{1}{\mu} \dfrac{\sinh u}{\cosh v} & \dfrac{\cosh (u-v)}{\cosh v} \end{bmatrix}^n$$

$$= \begin{bmatrix} \dfrac{\cosh\,(nu+v)}{\cosh v} & \mu\dfrac{\sinh nu}{\cosh v} \\[2ex] \dfrac{1}{\mu}\dfrac{\sinh nu}{\cosh v} & \dfrac{\cosh\,(nu-v)}{\cosh v} \end{bmatrix} \quad \ldots \quad (4)$$

Proof: By matrix multiplication,

$$\begin{bmatrix} \dfrac{\cosh\,(ru+v)}{\cosh v} & \mu\dfrac{\sinh ru}{\cosh v} \\[2ex] \dfrac{1}{\mu}\dfrac{\sinh ru}{\cosh v} & \dfrac{\cosh\,(ru-v)}{\cosh v} \end{bmatrix} \begin{bmatrix} \dfrac{\cosh\,(su+v)}{\cosh v} & \mu\dfrac{\sinh su}{\cosh v} \\[2ex] \dfrac{1}{\mu}\dfrac{\sinh su}{\cosh v} & \dfrac{\cosh\,(su-v)}{\cosh v} \end{bmatrix}$$

$$= \begin{bmatrix} \dfrac{\cosh\left\{(r+s)u+v\right\}}{\cosh v} & \mu\dfrac{\sinh\,(r+s)u}{\cosh v} \\[2ex] \dfrac{1}{\mu}\dfrac{\sinh\,(r+s)u}{\cosh v} & \dfrac{\cosh\left\{(r+s)u-v\right\}}{\cosh v} \end{bmatrix} \quad (5)$$

for all integer and fractional values of r, s.

Now, if $r = s = 1$ in (5) we obtain $[a]^2$, where $[a]$ is defined by (4). The theorem follows by induction.

The above method, derived for 2×2 matrices of determinant unity,* may obviously be extended to any non-singular 2×2 matrix by recourse to (2). For example

$$[A]^n = |A|^{n/2}[a]^n \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

where $[a]^n$ is given, according to the theorem, by (4).

It will be noted that the 'power theorem' just derived avoids the necessity of explicitly deriving the latent roots of the matrix as a preliminary to raising it to a power n. In the case of fractional powers, (4) gives at least one solution of the equation $y = [a]^n$.

[It is of interest to note in passing that the latent roots of the matrix on the r.h.s. of (4) are

$$\begin{aligned} \lambda_1 &= e^{nu} \\ \lambda_2 &= e^{-nu} \end{aligned} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

and they are therefore independent of the two parameters v and μ.]†

An alternative version of the power theorem, which has particular application to iterative networks, is as follows:

$$[a]^n = \begin{bmatrix} \cosh u + k\sinh u & \mu\sqrt{1-k^2}\,\sinh u \\[1ex] \dfrac{1}{\mu}\sqrt{1-k^2}\,\sinh u & \cosh u - k\sinh u \end{bmatrix}^n$$

$$= \begin{bmatrix} \cosh nu + k\sinh nu & \mu\sqrt{1-k^2}\,\sinh nu \\[1ex] \dfrac{1}{\mu}\sqrt{1-k^2}\,\sinh nu & \cosh nu - k\sinh nu \end{bmatrix} \quad (4a)$$

where*

$$\left.\begin{aligned} \cosh u &= \tfrac{1}{2}(a_{11} + a_{22}) \\ k\sinh u &= \tfrac{1}{2}(a_{11} - a_{22}) \\ \mu^2 &= \frac{a_{12}}{a_{21}} \end{aligned}\right\} \quad \ldots \quad \ldots \quad (8)$$

In the case of repeated asymmetrical 4-poles of iterative impedances Z_1 and Z_2 and of propagation constant γ, the parameters u, k, and μ correspond, in the transmission (or A matrix), to the following relations

$$\left.\begin{aligned} u &= \gamma \\ k &= \frac{Z_1 - Z_2}{Z_1 + Z_2} \\ \mu^2 &= Z_1 Z_2 \end{aligned}\right\} \quad \ldots \quad \ldots \quad (9)$$

Continued Products

It follows from (5) that the continued product

$$\begin{bmatrix} \dfrac{\cosh(a_1u+v)}{\cosh v} & \mu\dfrac{\sinh a_1u}{\cosh v} \\[2ex] \dfrac{1}{\mu}\dfrac{\sinh a_1u}{\cosh v} & \dfrac{\cosh(a_1u-v)}{\cosh v} \end{bmatrix} \cdot \begin{bmatrix} \dfrac{\cosh(a_2u+v)}{\cosh v} & \mu\dfrac{\sinh a_2u}{\cosh v} \\[2ex] \dfrac{1}{\mu}\dfrac{\sinh a_2u}{\cosh v} & \dfrac{\cosh(a_2u-v)}{\cosh v} \end{bmatrix}$$

$$\times \ldots \begin{bmatrix} \dfrac{\cosh(a_nu+v)}{\cosh v} & \mu\dfrac{\sinh a_nu}{\cosh v} \\[2ex] \dfrac{1}{\mu}\dfrac{\sinh a_nu}{\cosh v} & \dfrac{\cosh(a_nu-v)}{\cosh v} \end{bmatrix}$$

$$= \begin{bmatrix} \dfrac{\cosh\left\{(a_1+a_2+\ldots a_n)u+v\right\}}{\cosh v} & \mu\dfrac{\sinh\,(a_1+a_2+\ldots a_n)u}{\cosh v} \\[2ex] \dfrac{1}{\mu}\dfrac{\sinh\,(a_1+a_2+\ldots a_n)u}{\cosh v} & \dfrac{\cosh\left\{(a_1+a_2+\ldots a_n)u-v\right\}}{\cosh v} \end{bmatrix} \quad \ldots \quad \ldots \quad (10)$$

or in contracted notation:

$$\frac{1}{\cosh^n v}\prod_{s=1}^{n}\left\{\begin{bmatrix} \cosh(a_su+v) & \mu\sinh a_su \\ \dfrac{1}{\mu}\sinh a_su & \cosh(a_su-v) \end{bmatrix}\right\}$$

* This class of matrices corresponds to the transmission or A matrix of 4-poles which obey the law of reciprocity.

† The reader is reminded that the latent roots of the 2×2 matrix $\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$ are derived by solving the characteristic equation $\begin{vmatrix} a_{11}-\lambda & a_{12} \\ a_{21} & a_{22}-\lambda \end{vmatrix} = 0$; i.e., $(a_{11}-\lambda)\,(a_{22}-\lambda) - a_{12}a_{21} = 0$.

* The k in (8) is derived from the parameter v in (3a) by the relation $k = \tanh v$. It follows that $v = \frac{1}{2}\log\,(Z_1/Z_2)$.

$$= \frac{1}{\cosh v}\begin{bmatrix} \cosh\left\{\sum_{s=1}^{n} a_s u + v\right\} & \mu \sinh\left\{\sum_{s=1}^{n} a_s u\right\} \\ \frac{1}{\mu}\sinh\left\{\sum_{s=1}^{n} a_s u\right\} & \cosh\left\{\sum_{s=1}^{n} a_s u - v\right\} \end{bmatrix} \quad \text{(10a)}$$

Alternatively, in terms of the parameters u, k, μ in expression (4a) we have

$$\prod_{s=1}^{n}\left\{\begin{bmatrix} \cosh a_s u + k \sinh a_s u & \mu\sqrt{1-k^2}\sinh a_s u \\ \frac{1}{\mu}\sqrt{1-k^2}\sinh a_s u & \cosh a_s u - k \sinh a_s u \end{bmatrix}\right\}$$

$$\equiv \begin{bmatrix} \cosh\left\{\sum_{s=1}^{n} a_s u\right\} + k \sinh\left\{\sum_{s=1}^{n} a_s u\right\} & \mu\sqrt{1-k^2}\sinh\left\{\sum_{s=1}^{n} a_s u\right\} \\ \frac{1}{\mu}\sqrt{1-k^2}\sinh\left\{\sum_{s=1}^{n} a_s u\right\} & \cosh\left\{\sum_{s=1}^{n} a_s u\right\} - k \sinh\left\{\sum_{s=1}^{n} a_s u\right\} \end{bmatrix} \quad \ldots \quad \text{(10b)}$$

In expressions (10a), (10b) it will be noted that the argument $(a_1 + a_2 + \ldots + a_n)u$ on the r.h.s. is the sum of the arguments $a_s u$ in the continued product. This corresponds in the iterative connection of 4-poles to summation of propagation constants under matched conditions. Here we require the following relations [analogous to those in (9)]

$$\left.\begin{aligned} a_s u &= \gamma_s \\ k &= \frac{\mathcal{Z}_1 - \mathcal{Z}_2}{\mathcal{Z}_1 + \mathcal{Z}_2} \\ \mu^2 &= \mathcal{Z}_1 \mathcal{Z}_2 \end{aligned}\right\} \quad \ldots \quad \text{(11)}$$

Wedge Theorem

A second continued product theorem is as follows

$$\prod_{s=1}^{n}\left\{\begin{bmatrix} \lambda \cosh u & \frac{1}{k\lambda^{2s-2}}\sinh u \\ k\lambda^{2s-2}\sinh u & \frac{1}{\lambda}\cosh u \end{bmatrix}\right\}$$

$$\equiv \begin{bmatrix} \lambda^n \cosh nu & \frac{1}{k\lambda^{n-1}}\sinh nu \\ k\lambda^{n-1}\sinh nu & \frac{1}{\lambda^n}\cosh nu \end{bmatrix} \quad \ldots \quad \text{(12)}$$

The proof is readily established by induction.

This theorem is applicable to a chain of n 4-poles matched in image impedance at junctions. Let $\mathcal{Z}_I$ and $\mathcal{Z}_{II}$ be the image impedances of the first section, θ be the transfer constant of each section, and

$$u \doteq \theta;\ \lambda^2 = \mathcal{Z}_I/\mathcal{Z}_{II};\ \frac{1}{k} = \mathcal{Z}_0 = \sqrt{\mathcal{Z}_I \mathcal{Z}_{II}} \quad \text{(13)}$$

It can be shown that all impedances at corresponding points in the sth section will be $1/\lambda^{2s-2}$ times those in the first section. This change of impedance by geometrical progression suggests the name of 'wedge theorem' for expression (12). This theorem can obviously be extended to the case where the parameters u, λ, (θ, λ) are different in each section, say u_s, λ_s, (θ_s, λ_s) in the sth section. It may then be expressed as follows

$$\prod_{s=1}^{n}\left\{\begin{bmatrix} \lambda_s \cosh u_s & \frac{1}{k(\lambda_1\lambda_2\ldots\lambda_{s-1})(\lambda_2\lambda_3\ldots\lambda_s)}\sinh u_s \\ k(\lambda_1\lambda_2\ldots\lambda_{s-1})(\lambda_2\lambda_3\ldots\lambda_s)\sinh u_s & \frac{1}{\lambda_s}\cosh u_s \end{bmatrix}\right\}$$

$$\equiv \begin{bmatrix} (\lambda_1\lambda_2\ldots\lambda_n)\cosh(u_1+u_2+\ldots u_n) & \frac{1}{k(\lambda_2\lambda_3\ldots\lambda_n)}\sinh(u_1+u_2+\ldots u_n) \\ k(\lambda_2\lambda_3\ldots\lambda_n)\sinh(u_1+u_2+\ldots u_n) & \frac{1}{(\lambda_1\lambda_2\ldots\lambda_n)}\cosh(u_1+u_2+\ldots u_n) \end{bmatrix} \quad \ldots \quad \text{(14)}$$

Let

$$\left.\begin{aligned} u_s &= \theta_s \\ \lambda^2{}_s &= \mathcal{Z}_s/\mathcal{Z}_{s+1} \\ \frac{1}{k} &= \mathcal{Z}_0 = \sqrt{\mathcal{Z}_I \mathcal{Z}_{II}} \end{aligned}\right\} \quad \ldots \quad \text{(15)}$$

where θ_s is the transfer constant of the sth section, $\mathcal{Z}_s$ and $\mathcal{Z}_{s+1}$ are the input and output image impedances of the sth section, and $\mathcal{Z}_I$, $\mathcal{Z}_{II}$ are the input and output image impedances of the first section. Expression (14) is then the matrix representation of n dissimilar 4-poles, matched in image impedance at their junctions. It will be noted that the transfer constant of the chain of 4-poles is the sum of the transfer constants of each section. This is a fundamental property of chains of networks matched in this way.

The above expression has particular relevance in the study of 'tapered' networks, corresponding in behaviour to continuously tapered transmission lines.

Acknowledgment is due to the Director of Engineering, B.B.C., for permission to publish this paper.

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.

Coherent and Incoherent Detectors

SIR,—My article on this subject in the March issue contains an obscure error which has come to my notice. The results and conclusions are not affected by it, but it is nevertheless worth pointing out.

In dealing with power in the coherent detector prior to equation (9), it is stated that, for the case considered, $V = s + n \cos \phi$ so that the statistical mean power in the resistors R in Fig. 5 (a) is proportional to $s^2 + n^2/2$. This is not correct for, on combining Figs. 2 and 5 (a), $V = [s^2 + n^2 + 2ns \cos \phi]^{1/2}$. The power in the resistors is therefore proportional to $s^2 + n^2$.

Nevertheless, the conclusion that the coherent detector offers a 3-dB improvement in signal/noise power over the linear diode detector is correct. In measuring detector output power one is concerned with the power developed in a resistor connected to the output terminals. By virtue of the additional connections to the junction point of resistors R in Fig. 5 (a), these resistors do not constitute a simple load across the output terminals. If an additional resistor were connected across the output (so as to load the circuit to a negligible extent), the voltage across it would be $s + n \cos \phi$ and the statistical mean power in it would be proportional to $s^2 + n^2/2$. Much simpler reasoning gives the correct result!

I am indebted to Professor F. G. Heymann who first pointed out the anomaly to me.

R. KITAI

Department of Electrical Engineering,
University of the Witwatersrand, Johannesburg.
12th April 1957.

Network Matching Problems

SIR,—May I add a further amplification stage to Mr. Topple's excellent letter in your April issue.

First, I was aware of the number of mathematical solutions involved in example 3. As might be inferred, the second solution was not referred to as "the alternative", but simply as "an alternative". The wording was so chosen that a discussion of the uniqueness was not demanded. It was required simply to illustrate a construction, with as few complications as possible; but the particular solutions chosen would be expected to be practical ones. Now if solutions 3 and 4 are examined it will be doubted whether they fall into that category. One consists of a shunt 95 ohms inductive and a series 169 ohms capacitive arm. A series capacitor is undesirable because of its stray capacitance; for one thing, moreover, this solution violates a fundamental rule that where possible the low-pass form of the network should be used on account of its harmonic reducing property. Therefore it is rejected in favour of that illustrated in Fig. 4 (b). The other solution 4 has a shunt arm of about 180 ohms inductive and a series arm of about 169 ohms inductive also. This represents a grand total of, say, 350 ohms as against a total of 130 ohms in the comparable solution shown in Fig. 4 (a). Why consider using a big coil when a small one will do the job and do it better, with less energy storage and therefore with less adverse effect on the bandwidth, not to mention with less financial cost?

However, perhaps I should have stated that the correct thing to do, in general, is to carry out the impedance transformation via the shorter permissible paths, say, from P to C in Fig. 4, rather than by the longer routes. But the user will do this intuitively anyway and in the desire to keep well within the boundaries of the graph paper.

To draw attention to the possibility that the network could be orientated differently (after the manner of solutions 3 and 4 above) a subsequent example was constructed, ensuring this time that the solution would be a suitable one. Here I disagree with Mr. Topple. Only one solution is possible, for the other alleged one does not satisfy the stated condition "a capacitor forming its shunt arm".

Providing that one regards constant conductance and constant susceptance loci as elementary, it is a neat way of treating example 1. It is, perhaps, less attractive when extended to subsequent examples. In example 3, Mr. Topple might have ignored the circle OCB and instead simply joined O to A′ (the conjugate of A), erecting a perpendicular at A′ to get the same point B. Incidentally, his paragraph 3 contains the words "variable resistance" instead of "variable reactance". His approach here seems to involve splitting the network and remembering that the impedance looking one way is the complex conjugate of that looking the other way. This might be a pitfall and a source of confusion to the student who may have been told that load and line should be matched on a non-reflective basis whereas here matching is on a maximum power transfer basis. This hardly arises in the method I have described where the characteristic impedance of the r.f. transmission line is real, as it usually is.

However, his method is very elegant and gives the same result in the end. But an interpretation and title other than "constant susceptance" or "constant conductance" would need to be put on the locus OCB, when he uses it in examples 3 and 4.

JOHN DEIGNAN

Engineering Dept., Radio Eireann.
10th April 1957.

Dilemmas in Transmission-Line Theory

SIR,—Professor Chipman, in his article on Transmission-Line Theory (p. 64, February), raises the question of the 'optimum' termination for a transmission line, in the sense of the value of load impedance which makes the line losses a minimum for a given received power. Professor Chipman's treatment is complicated by the effect of the load upon the power transfer between the source and the line, but an alternative method based upon the equations

$$V_1 = V_2 \cosh \gamma l + I_2 Z_0 \sinh \gamma l$$
$$I_1 = I_2 \cosh \gamma l + V_2/Z_0 \,.\, \sinh \gamma l$$

can lead to an expression for the line efficiency (i.e., power output/power input) independent of the generator impedance, and this applies in the case of any symmetrical passive network, not only for a transmission line.

The power output, $W_2 = (V_2\, I_2^* + V_2^*\, I_2)/2$, with a similar expression for the power input, W_1. If $Z_L = |Z_L| \angle \phi_L$, $Z_0 = |Z_0| \angle \phi_0$, then the ratio of the input power to the output power is

$$\frac{W_1}{W_2} = \frac{\cosh 2\alpha l \cos \phi_0 \cos (\phi_0 - \phi_L) + \cos 2\beta l \sin \phi_0 \sin (\phi_0 - \phi_L)}{\cos \phi_L}$$
$$+ \left|\frac{Z_L}{Z_0}\right| \frac{\cos\phi_0 \sinh 2\alpha l + \sin \phi_0 \sin 2\beta l}{\cos \phi_L} + \left|\frac{Z_0}{Z_L}\right| \frac{\cos\phi_0 \sinh 2\alpha l - \sin \phi_0 \sin 2\beta l}{\cos \phi_L}$$

The optimum load, Z_{Lopt}, making W_1/W_2 a minimum, may be found by differentiation and, as Professor Chipman points out, approaches Z_0^* as αl becomes large. The algebra is too lengthy to be given here, but some of the results may be of interest.

For the three cases of termination in Z_0, Z_0^* and Z_{Lopt}, the power ratios obtained are $e^{2\alpha l}$, $e^{2\alpha l} - (1 - \cos 2\phi_0)$ $(\cosh 2\alpha l - \cos 2\beta l)$ and $A + \sqrt{A^2 - 1}$, respectively, where $A = \cosh 2\alpha l \cos^2 \phi_0 + \cos 2\beta l \sin^2 \phi_0$.

For a transmission line, although Z_{Lopt} may be very different from Z_0^*, the change in line efficiency between the two terminations is small, giving a maximum difference of just over 1 dB for a line with negligible leakance and inductance when the nominal attenuation is about 3 dB.

D. H. BROWN

Department of Physics and Telecommunications,
The Woolwich Polytechnic,
London, S.E.18.
1st March 1957.

New Books

Circuit Theory and Design

By JOHN L. STEWART. Pp. 480 + xiv, with 468 illustrations. John Wiley & Sons, Inc., and Chapman & Hall Ltd., 37 Essex St., London, W.C.2. Price 76s.

As far as its subject matter and its mathematical level are concerned, the book under review occupies a position about halfway between specialist books on advanced mathematical network theory, and the usually rather cursory treatment of network problems in general books or courses on communication engineering. The author, who is Associate Professor of Electrical Engineering at the California Institute of Technology, states in the preface that it has been his "express intent to write this book so that it might prove effective in undergraduate courses without compromising its value in graduate study". He regards the poles and zeros of network functions (in the complex frequency plane) as the most important concepts and tools for circuit analysis and design and describes the purpose of his book as follows: "Although pole-zero methods have been employed by high-level system designers and network synthesis people for several years, the technique has not become nearly as widespread as is justified. . . . Because a descriptive and relatively thorough text has not been available, the student as well as his teacher has remained partially unaware of pole-zero methods. This book has been written to help to fill the void."

Here a few remarks on the present state of network theory and engineering are relevant. In many practical filter-design problems two different approaches are possible; either by means of classical image parameter methods (mainly associated with the name of Zobel) or by means of modern synthesis methods (due to Foster, Cauer, Guillemin, Piloty, Norton, Brune, Bode, Darlington and many others). The modern methods which are highly mathematical are studied, and occasionally practised, by a small number of 'mathematical engineers', whereas the classical methods (frequently in an oversimplified form) are the routine tool of a much greater number of communication engineers who regard the mathematical formulations of the modern methods sometimes with suspicion and often with little understanding. However, there can be no doubt that the modern methods give us a greater insight into the 'mechanism' of network behaviour and lead in many design problems to better technical and more economical solutions (admittedly at the price of more computational work). In this situation, any book which helps to bridge the gap between the two different methods of attack is very welcome, and the book under review, which seems to be the first of this kind, performs therefore a real and necessary service.

The field which Dr. Stewart is trying to cover is very large, as shown by the chapter headings, which are self-explanatory: 1. Circuit analysis; 2. The poles and zeros of functions; 3. The poles and zeros of networks; 4. Elementary synthesis and numerical procedures; 5. Some important gain functions; 6. An introduction to modern synthesis; 7. Image parameters; 8. Conventional filters; 9. The circuit representation of vacuum tubes; 10. Low-pass amplifiers; 11. Band-pass amplifiers; 12. Feedback amplifiers and stability; 13. Oscillators; 14. Servomechanism functions. At the end of each chapter some problems are given. However, as the solutions are not provided, the reader may find it necessary to enlist outside help for checking his results. References to important text-books and original publications are given separately for each chapter, with brief comments which are very helpful.

Both logically and from an engineering point of view the inclusion of amplifiers, oscillators and servomechanism in a book on circuit theory is fully justified. However, the reviewer feels that the chapter on servomechanisms is much too short to be of real use to uninitiated readers and too elementary for experts. The chapters on valves and valve circuits, on the other hand, form an integral part of the book; but even here it might perhaps have been of greater use to the reader if the preceding chapters dealing with passive circuits had been enlarged by relegating active circuits to a second volume. This might have enabled the author to deal in Chapters 5 and 6 with such important practical problems as filters which exhibit Chebyshev (i.e., equal ripple) behaviour both in the pass-band and in the stop-band and with filters having Chebyshev behaviour in the pass-band which can be designed to meet arbitrary attenuation requirements in the stop-band (Darlington's 'reference filter' method). Due to these and other similar omissions the discussion of some advanced design ideas stops just short of the point at which the reader would be able to apply them to practical problems without any need for referring to the relevant original publications. Similarly, the treatment of conventional filters is not in itself sufficient for average practical purposes. However, comments as these are bound to be somewhat subjective, and any author has clearly to make his own selection of the topics to be covered. Within the limits indicated, the book deals with a great number of questions of both theoretical and practical interest in a novel and stimulating way and should therefore appeal to a wide circle of readers.

Some of the terms and symbols employed by Dr. Stewart are not those in current use, and some of the expressions occurring in his book are rather colloquial and picturesque (e.g., 'brick-wall' functions). However, this informality of style is rather attractive and suits the unconventionality of approach. As far as the mathematical treatment is concerned, a book which deliberately aims at an 'intermediate' level (and is intended for both graduate and undergraduate studies) is likely to aim too high for some readers and too low for others. On the whole, the mathematical discussions are very clear and as simple as possible but, occasionally, over-condensed mathematical arguments have slipped in which will make it difficult for beginners to use the book without the help of a teacher. One particular case is worth mentioning: when discussing the low-pass band-pass analogy the author states that the transformation of a low-pass pole leads to a pair of poles *and to a zero at zero frequency* (Chapter 4, p. 140). This is an over-simplification which happens to be correct for a function of the form $1/(p + a)$ but not for a function of the form $p/(p + a)$. The correct, generally valid, method is to regard the transformation of the low-pass *function* as the fundamental operation. Then it is seen that each low-pass zero always yields two band-pass zeros, and each low-pass pole two band-pass poles. The band-pass zero at zero frequency in the first example is produced by a low-pass zero at infinite frequency. There is also a band-pass zero at infinite frequency (not mentioned by the author). Errors of this kind are, in the reviewer's opinion, due to an occasional overstressing of the concept of 'pole-zero methods', in situations in which a slightly more pedestrian mathematical approach would automatically lead to the correct results. It should be easy to correct such passages in a second edition.

Summarizing, it can be stated that Dr. Stewart has written a most useful book which proves that even difficult mathematical engineering problems can be treated in a 'human' and comparatively simple manner. It can be warmly recommended to anybody interested in the subject of circuit theory, particularly in questions relating to filters and filter amplifiers.

W.S.

Profitable Radio Troubleshooting

By WILLIAM MARCUS and ALEX LEVY. Pp. 330. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 34s.

In addition to information on servicing a.m. radio receivers, the book has sections on starting and running a servicing business.

Frequency Modulation

By L. B. ARGUIMBAU and R. D. STUART. Pp. 96. Methuen Monograph. Methuen & Co. Ltd. Ltd., 36 Essex Street, London, W.C.2. Price 8s. 6d.

Siebschaltungstheorie

By RICHARD FELDTKELLER. Pp. 200. S. Hirzel Verlag, Birkenwaldstrasse 185, Stuttgart N, Germany. Price D.M. 25.40.

Werner von Siemens Lebenserinnerungen

Pp. 307. Published by Prestel Verlag, Munich, Germany. Price D.M. 14.50.

Handbook of Basic Circuits. TV—FM—AM

By MATTHEW MANDL. Pp. 365. The Macmillan Company, New York and London. London branch: 10 South Audley Street, London, W.1. Price 52s. 6d.

Pictorial Microwave Dictionary

By VICTOR J. YOUNG and MEREDITH W. JONES. Pp. 116. John F. Rider Publisher Inc., 116 West 14 Street, New York 11. Price $.2.95.

BRITISH INSTITUTION OF RADIO ENGINEERS

Papers to be read at "ELECTRONICS IN AUTOMATION" Convention to be held in the Cavendish Laboratory, Cambridge.

27th June:

OFFICE MACHINERY AND INFORMATION PROCESSING

9.15 a.m.–12.30 p.m.

"The Development of a Business Computer System", A. St. Johnston, B.Sc. and S. L. H. Clarke, B.A.

"Ferroresonant Circuits for Digital Computers", D. A. Bell, Ph.D., M.A., B.Sc. and C. B. Newport, B.Sc.

"Automatic Reading of Typed or Printed Characters", C. E. G. Bailey, M.A.

"Techniques for using Computers for Office Work", E. A. Newman, B.Sc. and M. A. Wright, B.Sc.

"Logical Design of a Computer for Business Use", R. J. Froggatt, B.Sc.

"Integration of Computers with Factory Processes", A. H. Cooper.

MACHINE TOOL CONTROL

2.30 p.m.–5.30 p.m.

"Backlash and Hysteresis Effects in Automation Systems", Prof. L. M. Vallese, D.Sc.

"Automatic Positioning Systems for Machine Tools", C. Borley, C. Braybrook and L. Coates.

"The Inductosyn and its Application", H. J. Finden and B. A. Horlock.

"The Design of a Basic System of Position Control for the Traversing Tables of Machine Tools", K. J. Coppin, B.Sc., A.R.C.S.

"Numerically Controlled Machine Tools and the Production Engineer", O. S. Puckle, M.B.E.

"Some Aspects of the Application of Closed Loop Servo Systems", R. J. F. Howard.

28th June:

CHEMICAL AND OTHER PROCESSES

9.15 a.m.–12.30 p.m.

"An Electronic Three Term Controller", Z. Czajkowski, B.Sc.

"Instrumentation for the Control of Process Streams in Atomic Energy Projects", H. Bisby, B.Sc., A.K.C.

"Industrial Applications of A.C. Polarography", R. L. Faircloth, B.Sc. and D. J. Ferrett, M.A., D.Phil.

"Fluid Density Measurements by means of Gamma Ray Absorption", R. Y. Parry and A. E. M. Hodgson.

"Electronics and Process Control Systems", J. M. Keating, B.Sc. and P. V. Slee.

AUTOMATIC MEASUREMENT AND INSPECTION

2.30 p.m.–5.30 p.m.

"Automatic pH Control", R. S. Evans, M.A.(Cantab.).

"Automatic Control in Steel Strip Manufacture", G. Syke, Dipl.Ing.

"Automatic Ultrasonic Inspection", H. W. Taylor, B.Sc.

"Automatic Counting Techniques Applied to Comparison Measurement", C. C. H. Washtell.

"Automatic Inspection as the Key Control Element in Full Automation", J. A. Sargrove and D. L. Johnston, B.Sc.(Eng.).

29th June: SIMULATORS

9.15 a.m.–12.30 p.m.

"The Use of Radar Simulators in the Royal Navy", P. Tenger, B.Sc.

"An Analogue Computer for Fourier Transforms", Prof. D. G. Tucker, D.Sc., Ph.D.

"The Determination of System Transfer Functions from Normal Operating Data", J. G. Henderson, B.Sc. and C. J. Pengilley, B.E.(Hons.).

"Electronic Synthesis of Elongated Flexible Beams", M. Squires, B.Sc.

"Radar Simulators", L. J. Kennard and C. H. Nicholson.

"A Nuclear Power Plant Training Simulator for use at Calder Hall", I. Wilson, B.Sc.(Eng.) and L. A. J. Lawrence.

"Analogue Computers and their use in Nuclear Reactor Safety Studies", I. Wilson, B.Sc.(Eng.) and R. Potter, B.Sc.

"Computing Applications where Analogue Methods are Superior to Digital", R. J. Gomperts, L.ès.Sc., M.A.

"A High Speed Analogue-to-Digital Converter", G. J. Herring, M.Sc. and J. Lamb.

AUTOMATION IN THE ELECTRONICS INDUSTRY

2.30 p.m.–5.30 p.m.

"The Use of Printed Circuits in the Manufacture of Electronic Equipment", F. Hicks-Arnold.

"Electronic Heating and Automation", M. T. Elvy.

"Recent Advances in Automatic Component Assembly", K. M. McKee, B.Sc. and L. H. Gipps.

"Automatic Methods in Radio Manufacture Processing", D. Stevenson and R. B. Shepherd, B.Sc.

FACTS AND FIGURES ABOUT BRITAIN

Travellers overseas may not be aware that the Central Office of Information can provide booklets dealing with Britain and the Commonwealth which provide facts and other information useful to those who will be called upon to speak at meetings. "50 Facts about British Economy" is available from the F.B.I.; "A Commonwealth Compendium" is due for immediate publication; while "British Records and Achievements" is in course of preparation. Inquiries should be addressed to the Central Office of Information, Norgeby House, 83 Baker Street, London, W.1.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Deviations from nominal frequency for April 1957*

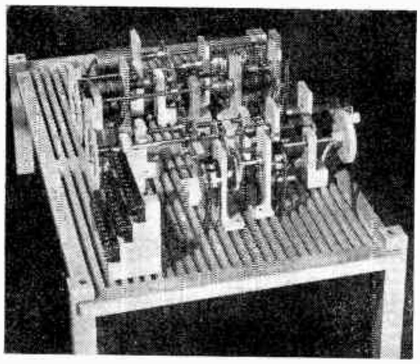
Date 1957 April	MSF 60 kc/s 2030 G.M.T. Parts in 10^9	Droitwich 200 kc/s 1030 G.M.T. Parts in 10^8
1	+ 3	0
2	+ 3	0
3	+ 3	− 1
4	+ 3	0
5	+ 3	0
6	+ 3	0
7	+ 3	0
8	+ 3	0
9	N.M.	+ 1
10	+ 4	+ 1
11	+ 4	+ 1
12	+ 4	+ 1
13	+ 4	+ 1
14	+ 4	+ 1
15	+ 4	+ 1
16	+ 4	+ 1
17	+ 5	+ 1
18	+ 5	+ 1
19	+ 4	+ 1
20	+ 4	0
21	+ 4	+ 1
22	+ 4	+ 1
23	+ 4	+ 1
24	+ 5	+ 1
25	+ 5	+ 2
26	+ 4	+ 2
27	+ 4	+ 2
28	+ 4	+ 1
29	+ 4	+ 1
30	+ 4	+ 2

* *Nominal frequency is defined to be that frequency corresponding to a value of* 9 192 631 830 *c/s for the N.P.L. caesium resonator. N.M. = Not Measured.*

New Products

'Breadboard' Servo Components

A 'breadboard' system, designed to save time in servomechanism development, is available from Vactric (Control Equipment) Ltd. The basic breadboard shown in the



photograph is supplemented by precision-made component supports, shaft supports fitted with precision ball-bearings, terminal block supports, locating blocks, shaft angle indicators, shaft couplers, cranking handles, gears, etc.
Vactric (Control Equipment) Ltd.,
196 *Sloane Street, London, S.W.*1.

Transistor Crystal Oscillator

Crystal Oscillator Type TS5 is a packaged oscillator which provides sine and square-wave outputs at a frequency of 10 kc/s. An XY flexure quartz crystal is used to provide accurate control, a preset capacitor external to the unit being used to set the oscillator to frequency initially. The circuit is encapsulated in synthetic resin with the

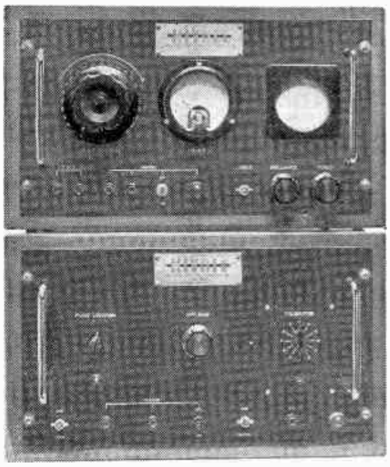
exception of the crystal, which is replaceable.

The oscillator may be used with two types of crystal, one having a zero temperature coefficient between 15°C and 20°C so that maximum accuracy is obtained at room temperature, and the other a zero temperature coefficient between 40°C and 50°C for applications where the ambient temperature is of this order. The stability of the oscillator at the point of zero temperature coefficient is of the order of 3 parts in 10^6.

The supply voltage is nominally 10 V, but the stage will function satisfactorily with supplies from 4–12 V. The output voltage on square waves is approximately 7·5 V peak-to-peak with a 10-V supply, and on sine waves approximately 5·6 V peak-to-peak. A low-impedance square-wave output is provided by an emitter-follower and provision is made for gating.
Venner Electronics Ltd.,
Kingston By-Pass, New Malden, Surrey.

Insulation Tester

The Hivolt type A.C.1 a.c. discharge detector enables the presence of discharges in small voids in insulation to be detected and their magnitude measured. A test voltage of up to 50 kV at 50 c/s is produced by a transformer and applied through a filter to the specimen and also, through a



blocking capacitor and matching unit, to a tuned amplifier.

The filter removes noise from the supply. The capacitor acts as a high-pass filter to reduce the 50-c/s input to the amplifier, which is tuned to 500 kc/s. The amplifier output is applied to a c.r. tube with an elliptical display.

In use, the voltage is raised until the display indicates the appearance of discharges within the specimen. A calibrated pulse is then applied to the tube and matched in amplitude to the discharge pulses. Finally, a simple calculation enables the amount of energy lost in the discharge to be found.

The equipment enables the non-destructive testing of insulation to be carried out and, by repeating the test at intervals, an indication of the condition of a dielectric can be obtained. The detection of an impending fault is thus possible.
Hivolt Ltd.,
91 *and* 93 *Princedale Road, London, W.*11.

Low-Capacitance Cables

Transradio Ltd. have developed ultra-low capacitance high-impedance coaxial cables of the construction shown in the diagram.

The characteristics of their type R1 cable, for example, are given as: impedance 139 ohms, capacitance 8·9 pF per foot, attenuation 0·27 dB per 100 ft at 1 Mc/s and 0·76 dB at 10 Mc/s, insulation resistance 10^7 megohms per 100 ft, diameter 9 mm.
Transradio Ltd.,
138 *Cromwell Road, London, S.W.*7.

Thermostatic Soldering Iron

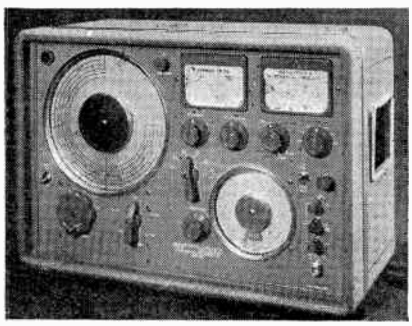
The Ceco thermostatic soldering iron is a small instrument suitable for use in electronic equipment. The thermostat, which can be adjusted by the user, is claimed to hold the bit temperature within

15°C of the nominal value. The 70-watt element is switched by a micro-switch attached to the thermostat; electrical interference is small.
Cardross Engineering Co. Ltd.,
Woodyard Road, Dumbarton, Scotland.

New F.M./A.M. Signal Generator

Marconi Instruments have introduced a new f.m./a.m. signal generator, the TF1066/1. This instrument is a special-quality version of the well-known TF1066.

The carrier-frequency range extends from 10–470 Mc/s and the output can be set at



any level between $0{\cdot}2\,\mu$V and 200 mV. A.M. is monitored and variable to any depth up to at least 40%.

Facilities for incremental tuning include stepped as well as continuous control. The stepped control of incremental frequency provides fixed positive or negative shifts of 5, 10 and 15 kc/s; the outstanding advantage of this feature is the ease with which rapid checks of receiver bandwidth can be made during production testing.

A fine-tuning control which covers a range of approximately 25 kc/s is incorporated. The carrier-frequency drift is no greater than $0{\cdot}0025$% in a 10-minute period, which corresponds to less than 800 c/s per minute at 300 Mc/s.

Marconi Instruments Ltd.,
St. Albans, Herts.

Direct-Reading Fluorimeter

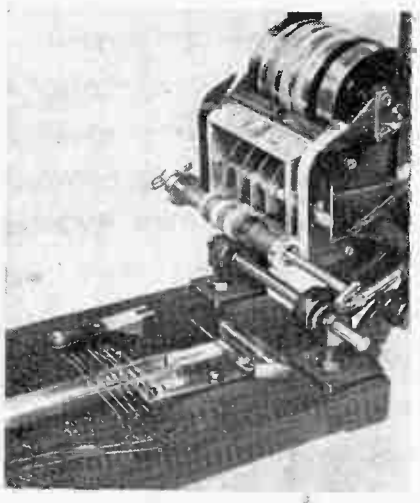
The Model 27 fluorimeter is a direct-reading device developed by Electronic Instruments Ltd. for use in quantitative chemical analysis based on the fluoresence of substances under ultra-violet light. The instrument, which makes use of a photocell, is first set against a standard substance with

which samples under test are subsequently compared. Very small changes in fluorescence can be detected.

Electronic Instruments Ltd.,
Lower Mortlake Road, Richmond, Surrey.

Colour-Coding Machine

Rejafix Ltd. have introduced a new machine which will put up to four different colour bands and one line of print in one

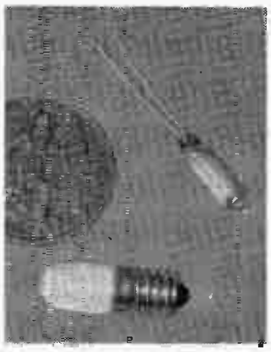


operation on fuses, resistors and similar components. The different colour-inked bands are automatically transferred to the surface of a printing pad, over which the article is rolled, picking up the colour coding in the process.

Rejafix Ltd.,
81-83 *Fulham High Street, London, S.W.*6.

Miniature Neon Lamps

The photograph shows two miniature fluorescent indicator lamps now being produced by Hivac Ltd. These are type F.1,



with wire ends, and type F.3, which has a small Edison screw cap.

Hivac Ltd.,
Stonefield Way, Victoria Road, South Ruislip, Middx.

Nickel-Cadmium Accumulators

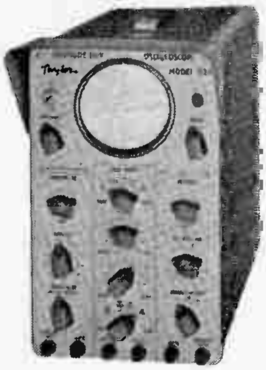
New 'Deac' hermetically-sealed nickel-cadmium accumulators, suitable for use in transistor equipment, are available from G. A. Stanley Palmer Ltd. The 5/900D is

rated at 6 V, $0{\cdot}9$ A-hour, and the 5/D1.5 is rated at 6 V, $1{\cdot}5$ A-hours.

G. A. Stanley Palmer Ltd.,
Maxwell House, Arundel Street, Strand, London, W.C.2.

New Oscilloscope

The Taylor oscilloscope model 32A has been designed primarily for the service engineer. A 4-inch tube is used and a graticule is provided to facilitate measurements along either axis. The time-base frequency range is 2 c/s–100 kc/s and the response of the Y amplifier, which is provided with a cathode-follower input stage, is given as 10 c/s–6 Mc/s, $+0{\cdot}5$ –3 dB, the Y sensitivity being 80 mV r.m.s. per inch of deflection. The X amplifier, which can be

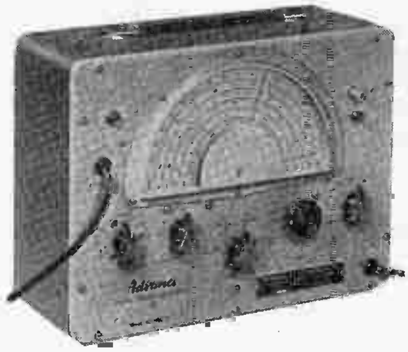


used for external signals, has a frequency range of 10 c/s–500 kc/s.

Taylor Electrical Instruments Ltd.,
419/424 *Montrose Avenue, Slough, Bucks.*

Wide-Band Signal Generator

The Advance type 62 signal generator is an inexpensive instrument designed for the service engineer. It covers the frequency range 150 kc/s to 220 Mc/s, the frequency accuracy being ± 1%. (An adjustable cursor is provided so that greater accuracies may



be obtained by setting the instrument against a standard frequency.) The oscillator can be amplitude-modulated (30% at 400 c/s) by an internal source; an audio output is also available. The radio-frequency output voltage is $1\,\mu$V to 100 mV in 75 ohms.

Advance Components Ltd.,
Roebuck Road, Hainault, Ilford, Essex.

New Tuning Indicator

The Brimar type EM840 is a miniature tuning indicator on the B9G base. The display takes the form of two vertical illuminated strips which approach one another as the triode grid of the valve is driven negative, and eventually merge to form a narrow rectangle. Zinc oxide is employed for the fluorescent screen, which is deposited on the inside of the glass envelope. This phosphor, which is claimed to have a longer life than willemite, glows with a pale bluish-green colour. It is suitable for use with external blue or yellow filters. The sensitivity, in terms of relative movement of the near edges of the two luminous areas, approaches 6 mm/V for small signals, and the indicator has a variable-mu characteristic.

Standard Telephones & Cables Ltd.,
Footscray, Kent.

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 journal titles conform generally with the style of the World List of Scientific Periodicals. An Author and Subject Index to the abstracts is published annually; it includes a selected list of journals abstracted, the abbreviations of their titles and their publishers' addresses. Copies of articles or journals referred to are not available from Electronic & Radio Engineer. *Application must be made to the individual publishers concerned.*

ACOUSTICS AND AUDIO FREQUENCIES

534.121 1623
The Composition Product of Difference Operators: Application to the Vibrations of Embedded Panels.—J. Hersch. (*C. R. Acad. Sci., Paris*, 14th Jan. 1957, Vol. 244, No 3, pp. 299–302.)

534.213 1624
Propagation of Elastic Waves in Medium with Cylindrical Ducts.—V. V. Tyutekin. (*Akust. Zh.*, July–Sept. 1956, Vol. 2, No. 3, pp. 291–301.)

534.213.4 1625
Acoustic Constants for Tubes of Small Cross-Section.—I. Barducci. (*Alta Frequenza*, Oct. 1956, Vol. 25, No. 5, pp. 355–377.) New formulae are derived for the calculation of primary and secondary acoustic constants, which allow for viscosity and thermal conduction but are not restricted by frequency and tube diameter limitations. The constants can be found with the aid of the graphs and tables given.

534.23 : 533.7 1626
Sound Radiation Pressure according to the Kinetic Theory of Gases.—V. Gavreau. (*J. Phys. Radium*, Oct. 1956, Vol. 17, No. 10, pp. 899–904.)

534.231.3 1627
Influence of the Subsonic Stream Velocity on the Radiation Impedance of a Piston with an Infinite Flange.—D. N. Chetaev. (*Akust. Zh.*, July–Sept. 1956, Vol. 2, No. 3, pp. 302–309.) A theoretical paper.

534.232 1628
Calculation of Radiation Impedance of some Distributed Radiator Systems.—M. I. Karnovski. (*Akust. Zh.*, July–Sept. 1956, Vol. 2, No. 3, pp. 267–278.) The real component of radiation impedance of various distributed systems of coherent radiators is determined. Groups of spherical radiators are considered.

534.232 : 546.431.824-31 1629
Cylindrical Radiator of Barium Titanate Ceramic Radiating along its Axis.—A. A. Anan'eva. (*Akust. Zh.*, July–Sept. 1956, Vol. 2, No. 3, pp. 323–325.)

534.61–8 1630
Theory of the Ultrasonic Interferometer.—V. A. Solov'ev. (*Akust. Zh.*, July–Sept. 1956, Vol. 2, No. 3, pp. 285–290.) New formulae are given for calculating the absorption coefficient for ultrasonic waves from the results of interferometric measurements.

534.7 1631
Significance of Time Factors in the Perception of Complex Sounds.—L. A. Chistovich. (*Akust. Zh.*, July–Sept. 1956, Vol. 2, No. 3, pp. 310–316.) Results are reported of experiments on the perception of sound in the presence of noise or interference.

534.78 : 621.396.5 1632
Instantaneous Speech Compressor.—C. R. Rutherford. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, pp. 168–169.) A miniature transistor compressor, for incorporation in the microphone lead of an aircraft transmitter, enables sideband power to be increased, giving greater range of communication.

534.84 1633
New Coefficients for the Assessment of Quality of Room Acoustics.—E. E. Golikov. (*Akust. Zh.*, July–Sept. 1956, Vol. 2, No. 3, pp. 255–266.)

534.851 : 681.85 1634
Locked Concentric-Grooved Disk for Use in Measurements of Disk-Reproducer Performance.—J. Feinstein. (*J. audio Engng Soc.*, April 1956, Vol. 4, No. 2, pp. 76–81.) The relative merits of signal grooves and closed concentric grooves for test records are discussed and some experimental results are given.

534.86 : 681.84 1635
The Radial Tone Arm—an Unconventional Phonograph Pickup Suspension.—H. E. Roys & E. E. Masterson. (*J. audio Engng Soc.*, July 1956, Vol. 4, No. 3, pp. 101–104.) The arrangement described uses a smooth rotating rod as lead screw and permits the pickup to follow a radial line, thus eliminating tracking error.

621.395.61.089.6 1636
Free-Field Technique for Secondary Standard Calibration of Microphones.—A. L. Seligson. (*J. audio Engng Soc.*, July 1956, Vol. 4, No. 3, pp. 110–115.) The method described includes automatic compensation for sound output-level changes with frequency of the source.

621.395.616 : 621.375.232.3 **1637**

A Cathode-Follower Pre-amplifier for Condenser Microphones.—Riéty. (See 1709.)

621.395.623.52 **1638**

A Semicircular Exponential Horn.—R. M. Cares. (*Audio*, Oct. 1956, Vol. 40, No. 10, pp. 26–29 . . 90.) An approximately semicircular horn made up of five square-pyramidal sections is described and illustrated; good response is obtained at frequencies down to 40 c/s.

621.395.623.7 **1639**

Recent Investigations of 'Son Rauque' in Loudspeakers.—J. B. Fischer. (*Arch. elekt. Übertragung*, Oct. 1956, Vol. 10, No. 10, pp. 441–454.) The conditions giving rise to subharmonic vibrations of loudspeaker cones are studied. Low mass, high stiffness and, above all, high damping of the cone material are desirable in order to keep such vibrations to a minimum. A certain amount of subharmonic vibration is tolerable; distortion due to this cause does not provide a criterion for subjectively perceived distortion. The vibration waveforms of a number of cones were observed; they indicate that the load exerts a radial rather than an axial action. Improvement is achieved by providing damping rings on the outer third of the cone.

621.395.623.743 **1640**

The Isophase Loudspeaker.—T. Lindenberg. (*J. audio Engng Soc.*, April 1956, Vol. 4, No. 2, pp. 56–59.) Brief description of two models of a push-pull 'inert-diaphragm' e.s. loudspeaker having a large diaphragm area. Their frequency response is flat from 400 c/s and 1 000 c/s respectively up to 20 kc/s.

621.395.625.3+534.862 **1641**

New Products and New Applications in the Magnetic-Tape and Film Fields.—E. W. Franck & E. Schmidt. (*J. audio Engng Soc.*, July 1956, Vol. 4, No. 3, pp. 90–100.) An outline of progress achieved up to 1954 with illustrations of some American equipment.

621.395.625.3 : 621.397.5 : 535.623 **1642**

Colour TV on Tape.—Lamont. (See 1920.)

AERIALS AND TRANSMISSION LINES

621.315.2 : 621.317.341.3 **1643**

Variation of Cable Loss with Standing Wave Ratio.—E. G. Hamer. (*J. Brit. Instn Radio Engrs*, Feb. 1957, Vol. 17, No. 2, pp. 121–124.) Formulae and nomograms are derived.

621.372 **1644**

Influence of Inhomogeneities on the Propagation of Electromagnetic Waves in Periodic Structures.—V. I. Bespalov & A. V. Gaponov. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 772–784.) The effect on the propagation of e.m. waves of random inhomogeneities in transmission lines with periodic-profile guide surfaces is considered theoretically using equivalent circuits. The treatment leads to a difference equation of the second order with random coefficients which is solved by pertubation methods. Formulae are obtained for the dispersion of the reflection coefficient at the entrance to the inhomogeneous section of the line. Examples considered include a comb delay line and an interdigital system.

621.372.2 **1645**

Dilemmas in Transmission-Line Theory.—E. G. Godfrey: I. F. Macdiarmid & H. J. Orchard: R. A. Chipman. (*Electronic Radio Engr*, April 1957, Vol. 34, No. 4, p. 150.) Comments on 984 of Apri and author's reply.

621.372.2 **1646**

Capacitance of Shielded Balanced-Pair Transmission Line.—A. W. Gent. (*Elect. Commun.*, Sept. 1956, Vol. 33, No. 3, pp. 234–240.) A concise formula for the capacitance is derived by the method of images, and its range of validity is shown to be wider than that of formulae previously obtained by various authors.

621.372.2 : 621.37.049.75 **1647**

Printed-Circuit Directional Coupler.—(*Electronic Radio Engr*, April 1957, Vol. 34, No. 4, pp. 133–134.) Description of a printed-circuit equivalent of the coaxial-cable directional coupler described by Monteath (2522 of 1955).

621.372.2.029.6 : 621.318.134 : 621.318.57 **1648**

Microwave Ferrite Phase Shifter.—S. Sensiper. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, p. 359.) A helical transmission line with a ferrite tube mounted inside the helix is described, and the performance as a sideband modulator is described and analysed.

621.372.51.012 **1649**

L-Network Design.—Mathis. (See 1686.)

621.372.8 **1650**

Note on Coaxial-Line/Waveguide Junctions. The Case of Thin Structures.—A. Leblond. (*Ann. Radioélect.*, Oct. 1956, Vol. 11, No. 46, pp. 331–338.) The general equations for the components of the input impedance are derived and the concept of 'thin structure' is defined. A method of determining the transmission parameters for such structures is described.

621.372.8 **1651**

Graphical Method of Determining the Efficiency of Two-Port Networks.—E. F. Bolinder. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, p. 361.)

621.372.8 : 621.376.22.029.64 **1652**

Amplitude Modulation of Microwaves by Tunable Transmission Waveguide Filters.—M. H. N. Potok & J. Barbour. (*J. Brit. Instn Radio Engrs*, Feb. 1957, Vol. 17, No. 2, pp. 109–113.) Modulation is effected by shifting the pass-band of the waveguide filter by the modulating signal. A linear response and a bandwidth > 4 kc/s have been obtained using simple components and circuits.

621.396.67.012.12 : 523.16 **1653**

Investigation of Aerials using Cosmic Sources of Radio Emission with Finite Dimensions.—O. A. Boguslavtsev, A. P. Molchanov, P. V. Olyanyuk & L. M. Ponomarenko. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 873–877.) The use of radiation from the sun and moon in determining aerial directivity characteristics is considered theoretically. Uniform disk brightness is assumed.

621.396.67.029.6 **1654**

A Universal Scanning Curve for Wide-Angle Mirrors and Lenses.—J. F. Ramsay. (*Marconi Rev.*, 4th Quarter 1956, Vol. 19, No. 123, pp. 150–159.) A curve is derived showing loss of gain on scanning of a coma-corrected focusing element-lens or mirror. Although normalized to an aperture of 100 λ and $F = 1$ it is applicable to other diameters and focal lengths at any wavelength, subject to restrictions dependent on the assumptions. Agreement with measured performances is shown. The use of the curve in determining the scanning performance of offset fed mirrors of circular profile symmetry is described.

621.396.67.029.64 **1655**

Misfocusing and the Near-Field of Microwave Aerials.—D. H. Shinn. (*Marconi Rev.*, 4th Quarter 1956, Vol. 19, No. 123, pp. 141–149.) "Curves are presented showing (*a*) the theoretical radiation patterns of a misfocused lens or mirror with a circular boundary and (*b*) the near-field of the same aerial correctly focused. Some practical applications of these are briefly discussed."

621.396.677.75 : 621.396.965 **1656**

Ferrod Radiator System.—F. Reggia, E. G. Spencer, R. D. Hatcher & J. E. Tompkins. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, pp. 344–352.) Arrays of microwave (3-cm-γ) ferrite dielectric tapered-rod aerials are described. The high dielectric constant of the ferrite allows the rod diameters to be about ¼ in. and a short feed section forming the mechanical support simplifies adjustment and reduces tolerances necessary for the rods. Methods of changing the polar diagram by magnetic switching have also been developed.

AUTOMATIC COMPUTERS

681.142 **1657**

An Accumulator Unit for a Dekatron Calculator.—R. Townsend & K. Camm. (*Electronic Engng*, Feb. 1957, Vol. 29, No. 348, pp. 58–64.) Decimal numbers may be added or subtracted, the sum being returned to the main store multiplied or divided by ten or unity. The calculator has a punched-card input.

681.142 : 51 **1658**

Introduction to a Theory of Ensembles based on the Prime Numbers Assimilable by Electronic Computers.—S. Sabliet. (*C. R. Acad. Sci., Paris*, 2nd Jan. 1957, Vol. 244, No. 1, pp. 35–38.) Computers of 'ordinator' type can be made to provide algebraic solutions of equations by coding the functions to be operated on as prime numbers.

681.142 : 621.314.2 **1659**

Application of a Digital Computer to the Design of Power Transformers to Specification.—C. L. Moore, W. T. Duboc & P. A. Zaphyr. (*Commun. & Electronics*, May 1956, No. 24, pp. 134–137. Discussion, pp. 137–138.)

681.142 : 621.314.63 **1660**

Application of Semiconductor Diodes in Circuits of Nonlinear Units of Electrical Analogue Apparatus.—G. M. Petrov. (*Avtomatika i Telemekhanika*, Aug. 1956, Vol. 17, No. 8, pp. 707–716.)

681.142 : 621.316.11 **1661**

Automatic Network Analysis with a Digital Computation System.—S. Y. Wong & M. Kochen. (*Commun. & Electronics*, May 1956, No. 24, pp. 172–175. Discussion, p. 176.) A general outline of the procedure and a method of solution are given.

681.142 : 621.318.134 **1662**

Ferrite Apertured Plate for Random Access Memory.—J. A. Rajchman. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, pp. 325–334.) An experimental prototype plate has 256 holes of 0·025 in. in a 0·830-in. square. A current of 330 mA reverses the magnetization around a hole in 1·5 μs and produces 30 mV. The hysteresis loop has good rectangularity and the properties of the holes are uniform within ±5%. Several novel switching principles are proposed, and it is claimed that the construction of a ferrite memory plate system with printed windings requires much less time and labour than corresponding techniques with conventional cores.

681.142 : 621.375.3 **1663**

A Magnetic-Amplifier Switching Matrix.—D. Katz. (*Commun. & Electronics*, May 1956, No. 24, pp. 236–241.) The circuit described translates a four-digit binary code into an electronically displayed decimal output.

681.142 : 621.395.625.3 **1664**

High-Density [magnetic-] **Tape Recording for Digital Computers.**—(*Elect. Mfg*, Nov. 1955, Vol. 56, No. 5, pp. 153, 290.) Digital pulse densities of up to 700/in. can be recorded by the method described which was developed by the National Bureau of Standards for use with the SEAC computer. See also 31 of 1956.

681.142.002.2 **1665**

Factory for Electronic Digital Computers.—(*Engineer, Lond.*, 26th Oct. 1956, Vol. 202, No. 5257, p. 593.) Design features of the 'Pegasus' and 'Mercury' computers are discussed.

CIRCUITS AND CIRCUIT ELEMENTS

621.314.6.01 **1666**

Rectifier and Contact-Rectifier Circuits.—O. B. Lupanov. (*C. R. Acad. Sci. U.R.S.S.*, 21st Dec. 1956, Vol. 111, No. 6, pp. 1171–1174. In Russian.) The synthesis of circuits realizing given functions and comprising a minimum number of elements is considered mathematically.

621.318.57 **1667**

Frequency-Sensitive Switching Circuit.—J. B. Earnshaw. (*Rev. sci. Instrum.*, Dec. 1956, Vol. 27, No. 12, pp. 1041–1043.) "A frequency-sensitive switching circuit is described which automatically selects between two ranges of an otherwise conventional frequency meter by switching the leak resistor of the integrating circuit."

621.318.57 : 621.387 **1668**

Dekatron Drive Circuit and Application.—M. Graham, W. A. Higinbotham & S. Rankowitz. (*Rev. sci. Instrum.*, Dec. 1956, Vol. 27, No. 12, pp. 1059–1061.) "A reliable, one-tube drive circuit for decade glow-transfer counter tubes is described. Application of the circuit is illustrated in a ten-channel glow-tube register with automatic electric-typewriter readout."

621.319.4 **1669**

Capacitors Subjected to Voltage Pulses: Prediction of Heating Effects.—J. Peyssou. (*Ann. Radioélect.*, Oct. 1956, Vol. 11, No. 46, pp. 281–292.) Heat dissipation can be calculated for pulse conditions by assuming the simultaneous application to the capacitor of all components of the Fourier analysis.

621.319.43 **1670**

Calculation of the Capacitance of a Variable High-Precision Capacitor with Plane Plates.—R. Lacoste & G. Giralt. (*C. R. Acad. Sci., Paris*, 14th Jan. 1957, Vol. 244, No. 3, pp. 321–324.) A systematic investigation is made of possible sources of error, and an upper limit for errors is determined as a function of the mechanical characteristics.

621.319.47 : 621.385.833.032.2 **1671**

Potential in Doubly Curved Condensers.—Albrecht. (See 1877.)

621.37.049.75 : 621.3.032.5 **1672**

New Design in Ruggedized P.C. [printed-circuit] **Connectors.**—H. E. Ruehlemann. (*Electronic Ind. Tele-Tech*, Oct. 1956, Vol. 15, No. 10, pp. 62–63 . . 162.)

621.37.049.75 : 621.319.4 **1673**

A Unique Printed-Circuit Capacitor.—J. R. Woods. (*Electronic Ind. Tele-Tech*, Oct. 1956, Vol. 15, No. 10, pp. 59, 157.) Description of a commercially produced ceramic capacitor which is leadless and flat, suitable for insertion into slots in the printed-circuit board prior to dip-soldering.

621.372.01 **1674**

Some Considerations on the Realizability of Electrical Circuits.—I. Gumowski. (*C. R. Acad. Sci., Paris*, 14th Jan. 1957, Vol. 244, No. 3, pp. 317–319.)

621.372.029.64 : 538.569.4 **1675**

Molecular Amplification and Generation of Microwaves.—Wittke. (See 1733.)

621.372.029.64 : 538.569.4 **1676**

Molecular-Beam Oscillator.—Basov. (See 1734.)

621.372.2 : 621.314.2 **1677**

Properties of an Adjustable Line Transformer.—H. K. Ruppersberg. (*Arch. elekt. Übertragung*, Oct. 1956, Vol. 10, No. 10, pp. 438–440.) Use of a six-terminal network with uniform input and output lines is discussed, and an analysis is made of the effect on the location of the input and output transformation reference points, and on the transformation factor, of moving a short-circuit along the second output line.

621.372.4 **1678**

The Decomposition into Energy Terms of the Operational Impedance of a Two-Terminal Network.—L. Lunelli. (*Alta Frequenza*, Oct. 1956, Vol. 25, No. 5, pp. 391–410.) Derivation of further theorems with reference to earlier work (39 and 3295 of 1956).

621.372.412.029.45 : 549.514.51 **1679**

Flexural-Mode Quartz Crystals as A.F. Resonators.—Bechmann & Hale. (See 1836.)

621.372.413 : [537.226+538.221 **1680**

Note on Cavity Perturbation Theory.—E. G. Spencer, R. C. LeCraw & L. A. Ault. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 130–132.) A criterion for the validity of the theory is presented.

621.372.5 **1681**

Synthesis of Linear Systems with the Aid of *RLC* Elements.—R. Kulikowski. (*Bull. Acad. polon. Sci., Classe 4e*, 1956, Vol. 4, No. 4, pp. 287–292. In English.)

621.372.5 **1682**

Synthesis of Transfer Functions with Poles Restricted to the Negative Real Axis into Two Parallel *RC* Ladders and an Ideal Transformer.—M. G. Malti & Hun Hsuan Sun. (*Commun. & Electronics*, May 1956, No. 24, pp. 165–171. Discussion, p. 171.)

621.372.5 **1683**

Network Synthesis for a Prescribed Impulse Response using a Real-Part Approximation.—R. A. Pucel. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 124–129.) A semi-graphical scheme is presented with examples illustrating synthesis procedure.

621.372.5.011.1 **1684**

The Synthesis of Loss-Free Quadripoles from Lines with Nonuniform Characteristic Impedance.—H. Meinke. (*Nachrichtentech. Z.*, Oct. 1956, Vol. 9, No. 10, pp. 457–461.) Approximation methods of solving impedance transformation problems by means of series expansions are outlined.

621.372.51 **1685**

Network Matching Problems.—E. L. Topple. (*Electronic Radio Engr*, April 1957, Vol. 34, No. 4, p. 151.) Comment on 1019 of April (Deignan).

621.372.51.012 **1686**

L-Network Design.—H. F. Mathis. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, pp. 186, 188.) Description of a technique for using a Smith chart to determine transducing networks for transmission lines and waveguides.

621.372.54 **1687**

Some Quadripole Transformations.—J. E. Colin. (*Câbles & Transm.*, Oct. 1956, Vol. 10, No. 4, pp. 314–334.) Norton's method of transformation is applied to several types of filter circuit and used to form three-branch networks. The negative capacitance arising from the transformation can be suppressed in the case of a band-pass filter derived from a low-pass filter. A summary of transformation formulae is appended.

621.372.54 **1688**

Graphical Construction of the Image Attenuation, with or without Losses, of a Ladder Filter with One or Two Cut-Off Frequencies.—J. Bimont. (*Câbles & Transm.*, Oct. 1956, Vol. 10, No. 4, pp. 335–355.) The nomogram method described is illustrated by a numerical example.

621.372.54 **1689**

The Transmission Constants of Networks with a Given Transient Response.—V. Fetzer. (*Nachrichtentech. Z.*, Oct. 1956, Vol. 9, No. 10, pp. 462–468.) The constants for low-pass and narrow band-pass filters are calculated by means of Laplace transformations. Formulae and curves are given for a number of input and response functions. See also 960 of 1955.

621.372.54 **1690**

The Characteristics of Parallel-T *RC* Networks.—D. H. Smith. (*Electronic Engng*, Feb. 1957, Vol. 29, No. 348, pp. 71–77.) Balanced and unbalanced networks are analysed and typical curves of magnitude and phase of the transmission ratio are given. The use of the unbalanced type in an oscillator is described.

621.372.54 : 621.396.621.54 **1691**

Some Aspects of Intermediate-Frequency Filtering in a Receiver.—J. Carteron. (*Câbles & Transm.*, Oct. 1956, Vol. 10, No. 4, pp. 263–278.) The design of ladder-type half-sections, including those of variable selectivity, and of improved crystal-filter networks is discussed. Examples of filter design calculations are given with tabulated values of attenuation and phase shift.

621.372.54+621.372.553] :621.397.24 **1692**

Filters and Delay Equalizers for Television Transmission on Cables.—Keil. (See 1917.)

621.372.56.029.62 **1693**

V.H.F. Variable Attenuators.—B. G. Martindill. (*Wireless World*, April 1957, Vol. 63, No. 4, pp. 181–182.) Continuously variable ladder attenuators suitable for use up to 200 Mc/s are formed by press stamping from a thin insulator base with a carbon coating.

621.372.57 **1694**

The Analytical Representation of Active Quadripoles.—J. Piesch. (*Arch. elekt. Übertragung*, Oct. 1956, Vol. 10, No. 10, pp. 429–437.)

621.372.57 **1695**

The Theory of Noisy Quadripoles and its Application.—(*Telefunkenröhre*, Oct. 1956, No. 33, pp. 1–145 & A1–A89.) A group of papers covering modern theory and applications. 68 references are given, some of which have been noted previously [e.g. 2665 of 1956 (Rothe & Dahlke) and 636 of 1957 (Bauer & Rothe)].

621.373 : 621.317.361 **1696**

Theory of the Spectral Line Width of Radio-Frequency Generators and its Measurement by the Method of I. L. Bershtein.—V. S. Troitski. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 818–830.) For Bershtein's paper (*Zh. tekh. Fiz.*, 1941, Vol. 11, No. 4, pp. 305–316), see 1649 of 1942.

621.373.029.64 : 621.396.822 **1697**

Noise-Diode Generator for the 3-cm Band.—S. I. Averkov, V. I. Anikin, D. M. Bravo-Zhivotovski, A. V. Gaponov, M. T. Grekhova, V. S. Ergakov, V. A. Lopyrev, M. A. Miller & V. A. Flyagin. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 758–771.) The construction and operation is described of a microwave noise generator in the form of a coaxial diode slot-coupled to a waveguide T-junction.

621.373.42 : 621.316.86 **1698**

The Use of Thermistors for the Compensation of Thermal Drift in Self-Oscillating Circuits.—P. Guené. (*Ann. Radioélect.*, Oct. 1956, Vol. 11, No. 46, pp. 317–330.) Formulae for calculating frequency drift are derived theoretically. Examples show that in the case of a particular 0·75–1·5-Mc/s oscillator the frequency drift can be reduced to about 3 parts in 10^6 per °C.

621.373.42 : 621.373.1.029.4 **1699**

Very-Low-Frequency Generator.—P. Dupin. (*C. R. Acad. Sci., Paris*, 14th Jan. 1957, Vol. 244, No. 3, pp. 319–321.) The arrangement described comprises a pair of rotating capacitors of complementary configuration connected in series and associated with an inductance so as to form a resonant circuit. A h.f. voltage of constant amplitude is applied, and sinusoidal-envelope voltages in phase opposition are derived from the two capacitances and rectified. The output frequency is dependent on the rotation rate.

621.373.421 **1700**

Constant-Frequency Oscillators.—D. A. Bell. (*Electronic Radio Engr*, April 1957, Vol. 34, No. 4, p. 150.) Comment on 697 of 1956 (Gladwin).

621.373.431 : 621.385.5 **1701**

Relaxation Oscillator using a Gated Beam Tube.—C. E. Tschiegg. (*Rev. sci. Instrum.*, Dec. 1956, Vol. 27, No. 12, pp. 1085–1086.)

621.373.52 : 681.142 **1702**

Linear Sweep-Voltage Generators and Precision Amplitude Comparator using Transistors.—L. C. Merrill & T. L. Slater. (*Elect. Commun.*, Sept. 1956, Vol. 33, No. 3, pp. 228–233.)

621.374 : 621.372.5 **1703**

Pulse Shaping to a Given Monotonic Discharge Function.—K. G. Fancourt & J. K. Skwirzynski. (*Marconi Rev.*, 4th Quarter 1956, Vol. 19, No. 123, pp. 176–182.) A method of approximating a required discharge function is described; it is realizable in the form of a *RC* network.

621.374.4 **1704**

Electronic Multiplier Circuit.—L. Sideriades & J. Brunel. (*C. R. Acad. Sci., Paris*, 7th Jan. 1957, Vol. 244, No. 2, pp. 176–178.) A multiplier derived from the four-position flip-flop circuit described by Sideriades (2339 of 1956) is discussed.

621.374.4 : 621.396.41 **1705**

Reference Generator for S.S.B. Systems.—M. I. Jacob. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, pp. 152–155.) "Applicable to scatter propagation, equipment uses stable frequency generator employing phase-locked oscillators to provide accurate reference frequencies for s.s.b. generator. Beam-switching tube used in frequency-dividing circuits permits coverage of 2 to 30-Mc/s range in 1-kc/s steps."

621.375.2.029.3 **1706**

Inexpensive High-Quality Amplifier.—P. J. Baxandall. (*Wireless World*, March & April 1957, Vol. 63, Nos. 3 & 4, pp. 108–113 & 168–172.) Design and construction details of an a.f. amplifier with 5-W push-pull output stage are given, with results of measurements and comparative listening tests.

621.375.2.029.3 **1707**

Design for a 50-Watt Amplifier.—W. I. Heath & G. R. Woodville. (*Wireless World*, April 1957, Vol. 63, No. 4, pp. 158–163.) Incorporates two pentodes Type KT88 in an 'ultralinear' output stage.

621.375.232.029.4 **1708**

An Output-Transformerless Amplifier.—H. Amemiya. (*J. audio Engng Soc.*, April 1956, Vol. 4, No. 2, pp. 72–75.) The amplifier described has a flat frequency response up to 30 kc/s with 20-dB negative feedback; its output is 3 W into 600 Ω for an input of 0·8 V.

621.375.232.3 : 621.395.616 **1709**

A Cathode-Follower Pre-amplifier for Condenser Microphones.—P. Riéty. (*Ann. Télécommun.*, Oct. 1956, Vol. 11, No. 10, pp. 198–206.) Several practical circuits are analysed with special attention to stability and low background noise.

621.375.3 **1710**

Magnetic Amplifiers.—(*Electronic Radio Engr*, April 1957, Vol. 34, No. 4, pp. 118–123.) A general discussion of the principles of operation, advantages and limitations is followed by a brief description of their various applications.

621.375.4 **1711**

Stability and Power Gain of Tuned Transistor Amplifiers.—A. P. Stern. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, pp. 335–343.) The theoretical maximum power gain realizable as a function of a required degree of stability is discussed for single- and multi-stage amplifiers.

GENERAL PHYSICS

530.1 : 51 **1712**

On the Perturbation Theory of Small Disturbances.—A. Dalgarno & A. L. Stewart. (*Proc. Roy. Soc. A*, 18th Dec. 1956, Vol. 238, No. 1213, pp. 269–275.) Conventional perturbation theory is re-examined and a number of useful properties are emphasized.

530.16 **1713**

Causality and the Dispersion Relation: Logical Foundations.—J. S. Toll. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1760–1770.) A rigorous proof is given, for a linear system, of the logical equivalence of strict causality ('no output before the input') and the validity of a dispersion relation, e.g. the relation expressing the real part of a generalized scattering amplitude as an integral involving the imaginary part.

535.14 **1714**

Light Waves and Photons.—(*Electronic Radio Engr*, April 1957, Vol. 34, No. 4, pp. 130–133.) A discussion of the particle theory of light in which the author endeavours to describe in simple terms the nature of the photon.

535.22 **1715**

New Method of Measuring the Velocity of Light.—K. S. Vul'fson. (*C. R. Acad. Sci. U.R.S.S.*, 11th Aug. 1956, Vol. 109, No. 5, pp. 929–930. In Russian.) A modified version of Fizeau's method is proposed. The equipment comprises a triggered light-pulse source, distant mirror, photocell and pulse amplifier, the output of which is used to trigger the source. The pulse repetition frequency is a function of the circuit delay constant, the light path length and the velocity of light. Using pulses of 10^{-7}–10^{-8} sec and a path a few metres long a result accurate to one part in 10^7–10^8 should be attainable.

535.33.07 **1716**

The Role of the Receiver in the Determination of the Elements of a Grating Spectrometer: Application to the Far Infrared ($20\,\mu < \lambda < 1\,000\,\mu$).—M. A. Hadni. (*Ann. Phys., Paris*, Sept./Oct. 1956, Vol. 1, pp. 765–778.) The prospects of improving resolution by using more powerful signal sources and appropriately designed radiation detectors are discussed.

537.226 : 530.145 : 538.569.4 **1717**

Quantum Theory of Dielectric Relaxation.—E. P. Gross & J. L. Lebowitz. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1528–1531.) The statistical behaviour of a system coupled to a reservoir at constant temperature is treated, assuming that the interactions are impulsive.

537.311 **1718**

The Electron-Phonon Interaction, according to the Adiabatic Approximation.—J. C. Taylor. (*Proc. Camb. phil. Soc.*, Oct. 1956, Vol. 52, No. 4, pp. 693–697.) Further application of Ziman's work (1355 of 1956) to calculate the self-energy of conduction electrons.

537.523 : 621.314.6 **1719**

Studies of Rectification in a Gas (Nitrogen) Discharge between Coaxial Cylindrical Electrodes: Part 3—Rectification in Full Ozonizers.—V. L. Talekar. (*J. Electronics*, Jan. 1957, Vol. 2, No. 4, pp. 341–357.) Potential variation of rectification is studied at pressures from 6 to 350 mm Hg. Parts 1 and 2: 1391 of May.

537.525 **1720**

The Generation of Direct Current by a High-Frequency Discharge: Part 1.—M. Chenot. (*J. Phys. Radium*, Oct. 1956, Vol. 17, No. 10, pp. 842–848.) Discussion of the results of further experiments on the effects previously investigated (2262 of 1955 and back references).

537.525 : 621.396.822 : 621.317.7.029.6 **1721**

Helix-Type Gaseous-Discharge Noise Sources at Low Plasma Densities.—H. Schnitger. (*J. Electronics*, Jan. 1957, Vol. 2, No. 4, pp. 368–377.) The behaviour of the positive column of a helium discharge is investigated theoretically and experimentally at 1·8 kMc/s. The measured attenuation shows good agreement with theory, but the noise figure is too low for the value predicted by the ambipolar diffusion theory.

537.525.5 : 538.561 **1722**

An 8-Volt Cold-Cathode Mercury Arc Emitting Microwaves.—K. D. Froome. (*Nature, Lond.*, 2nd Feb. 1957, Vol. 179, No. 4553, pp. 267–268.) A vacuum arc struck between a liquid Hg cathode and a vertical thin tungsten-wire anode emits microwave noise when running at minimum arc length. With the arc coupled to a coaxial-line resonator the measured output was about 50 μW in a band approximately 200 Mc/s wide centred on 3 kMc/s; under these conditions the potential difference across the arc was less than 7·5 V d.c.

537.533 **1723**

Electron Emission from Mechanically Worked Metal Surfaces on Oxidation.—J. Lohff. (*Z. Phys.*, 16th Oct. 1956, Vol. 146, No. 4, pp. 436–446.) Experimental results indicate that chemically active metals, after surface treatment with a steel brush, emit electron currents whose intensities are markedly sensitive to the presence of oxygen in the containing vessel, but not of nitrogen. The intensities are lower at higher temperatures. As a function of time after the treatment, the emission first increases and then decreases. Irradiation by u.v. or X rays gives rise to practically no delayed emission. These results are not consistent with the trap mechanism suggested e.g. by Seeger (2914 of 1955).

537.533 : 537.534.8 **1724**

Effect of Monolayer Adsorption on the Ejection of Electrons from Metals by Ions.—H. D. Hagstrum. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1516–1527.) Monolayer adsorption of a foreign gas (N_2, H_2 or CO) on an atomically clean tungsten surface decreases the electron yield, primarily at the expense of the faster electrons ejected from the metal.

537.56 : 533.7 **1725**

On the Dynamics of a Nonuniform Electrically Conducting Fluid.—G. H. A. Cole. (*Nuovo Cim.*, 1st Oct. 1956, Vol. 4, No. 4, pp. 779–785. In English.) First steps are taken towards building up a kinetic theory of ionized fluids under nonuniform conditions. The Boltzmann-Maxwell and Fokker-Planck equations are related to molecular data, and in this way the approximations involved in their use are made clear.

537.56 : 536.7 **1726**

Solution of Boltzmann's Equation for an Imperfect Lorenz Gas. Application to Weakly Ionized Gases.—M. Bayet, J. L. Delcroix & J. F. Denisse. (*C. R. Acad. Sci., Paris*, 7th Jan. 1957, Vol. 244, No. 2, pp. 171–173.) Extension of theory presented previously.

538.13 **1727**

Microinhomogeneities in Magnetic Fields.—H. H. Brown, Jr, & F. Bitter. (*Rev. sci. Instrum.*, Dec. 1956, Vol. 27, No. 12, pp. 1009–1012.) For a given magnet pole face, the field variations were found to be all about the same size; they decreased exponentially from the pole face.

538.56 : 536.33 **1728**

Thermal Radiation of Good Conductors.—M. L. Levin. (*Zh. eksp. teor. Fiz.*, Aug. 1956, Vol. 31, No. 2(8), pp. 302–316.) The radiation in the wave zone is calculated by methods of the electrodynamical theory of thermal fluctuations for the limiting cases of wavelengths small and large in comparison with the radiator dimensions. The radiation from bodies with surface anisotropies is studied. The fluctuation field near conducting surfaces (metallic plane, focus of parabolic mirror, and centre of spherical mirror) is considered. Fluctuation surface charges are calculated.

538.56 : 537.5 **1729**

Observation of Gyromagnetic Resonance of Electrons in a Disintegrating Plasma.—Yu. V. Gorokhov. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 794–797.) The experiments reported were performed on hydrogen and helium gas at pressures between 3×10^{-3} and 4 mm Hg in an aerial switch placed in a constant magnetic field.

538.566 : 535.42] + 534.26 **1730**

On the Propagation of Pulses: Part 1—Diffraction of Pulses by Wedges.—F. Oberhettinger. (*Z. Phys.*, 16th Oct. 1956, Vol. 146, No. 4, pp. 423–435. In English.) Diffraction of an e.m. or an acoustic pulse by a perfectly reflecting wedge is investigated, using a method based on representation of a function by a Laplace transform and on the solution of the corresponding time-harmonic problem.

538.566.2 **1731**

Propagation in a Gyrational Medium.—L. G. Chambers. (*Quart. J. Mech. appl. Math.*, Sept. 1956, Vol. 9, Part 3, pp. 360–370.) "The electromagnetic properties of media such that $\mathbf{D}=\epsilon\mathbf{E}+\xi\mathbf{H}$, $\mathbf{B}=\zeta\mathbf{E}+\mu\mathbf{H}$ are discussed. It is shown that each field component obeys the equation $\nabla^2\mathbf{F}+i\omega(\zeta-\xi)\nabla\times\mathbf{F}+\omega^2(\mu\epsilon-\zeta\xi)\mathbf{F}=0$ and that such media are accordingly doubly refracting. Integral forms for Maxwell's equations are also discussed."

538.569.4 : 621.372.029.64 **1732**

Geometrical Representation of the Schrödinger Equation for Solving Maser Problems.—R. P. Feynman, F. L. Vernon, Jr, & R. W. Hellwarth. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 49–52.) A simple rigorous geometrical picture is developed to describe the resonance behaviour of a quantum system when only a pair of energy levels is involved.

538.569.4 : 621.372.029.64 **1733**

Molecular Amplification and Generation of Microwaves.—J. P. Wittke. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, pp. 291–316.) A survey of theory and methods is given. At present, means of achieving low-noise low-level amplification by molecular resonance in gases have been obtained ; but bandwidths are low, although it should soon be possible to increase them using solid-state devices. Reduction in gain with frequency will probably preclude application at longer wavelengths, but possibilities are offered in the millimetre and sub-millimetre ranges.

538.569.4 : 621.372.029.64 **1734**

Molecular-Beam Oscillator.—N. G. Basov. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 752–757.) Brief description of a 23 870-Mc/s NH_3-beam oscillator. See also 3709 of 1956 (Basov & Prokhorov) and back references.

537.5 **1735**

Ionized Gases. [Book Review]—A. von Engel. Publishers : Clarendon Press, Oxford, 1955, 281 pp., 42s. (*Brit. J. appl. Phys.*, Dec. 1956, Vol. 7, No. 12, p. 455.) ". . . should be of real value to research workers . . ."

538.56 **1736**

Electromagnetic Waves. [Book Review]—G. Toraldo di Francia. Publishers : Interscience, New York and London, 320 pp., \$6 or 45s. (*Research, Lond.*, Nov. 1956, Vol. 9, No. 11, p. 448.) A treatment of fundamentals is presented which deviates in some respects from standard theory.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 **1737**

Radio Astronomy.—(*Telefunken Ztg*, Sept. 1956, Vol. 29, No. 113, pp. 143–198. English summaries, pp. 199–203.) A group of papers dealing with developments which led to the erection of the Stockert (West Germany) observatory and detailing its technical features and proposed research program. The issue includes the following papers:

Organization of the Technical Co-operation for the Construction of the Radio Telescope.—H. B. Speicher (pp. 144–146).

Radio Engineering, the Atmosphere and the Universe.—H. Rukop (pp. 146–147).

The Astronomical Research Program of the Bonn Radio Telescope.—F. Becker (pp. 148–151).

The Radio Emission from Interstellar Gas and its Measurement.—P. Mezger & W. Priester (pp. 152–156).

The Planning of the Construction of the Radio Observatory on the Stockert.—T. Pederzani (pp. 157–166).

Driving and Tracking Problems of Radio-Astronomy Receiving Equipment on the Stockert.—O. Mohr & H. Klessmann (pp. 166–173).

The Electrical System of Automatic Tracking Control.—H. Klessmann (pp. 174–181).

The Resolving Power of the R.F. Receiving Equipment of the Radio Telescope.—P. A. Mann & P. Mezger (pp. 182–191).

A Spectrometer for the 20-cm Band with Extremely High Resolution and Sensitivity.—K. W. Grimm (pp. 191–198).

523.16 **1738**

The Radio Observatory Stockert.—T. Pederzani. (*Elektrotech. Z.*, *Edn B*, 21st Oct. 1956, Vol. 8, No. 10, pp. 357–361.) Brief description of the 21-cm-λ receiver system and control equipment for the 25-m diameter parabolic reflector used in the first radio telescope installed in West Germany. See also 1737 above.

523.16 **1739**

Photometric Paradox at Radio Frequencies.—G. G. Getmantsev. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 838–839.) Conclusions based on data for metagalactic radio emission indicate that the photometric radius of the metagalaxy does not exceed 100 megaparsecs at radio frequencies. The problem of various 'clipping mechanisms' in the radio emission from distant metagalactic sources is briefly discussed.

523.16 **1740**

Preliminary Results of the Measurement of the Polarization of Cosmic Radio Emission at a Wavelength of 1·45 m.—V. A. Razin. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 846–851.) Weak ($\approx$4%) linear polarization of radiation from celestial regions outside the Milky Way was observed. The apparatus is briefly described.

523.16 **1741**

Parasitic Modulation.—N. V. Karlov. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 852–860.) Parasitic modulation in modulation-type radiometers for radio-astronomical observations is considered and the use of ferrite attenuators is mentioned.

523.16 **1742**

Multichannel Radiospectrograph and First Results of Observations.—V. V. Vitkevich, Z. I. Kameneva & D. V. Kovalevski. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 864–868.) The apparatus is described with the aid of a block diagram. The frequency band of 80–120 Mc/s is covered by eight receivers tuned to frequencies spaced at 5 Mc/s with bandwidth 1 Mc/s; the receiver noise factor is 5. Two parabolic reflectors with dimensions 18 × 8 m are used. Results of solar observations are also reported.

523.16 **1743**

Construction of Radiospectrograph NIZMIR.—Ya. I. Khanin & A. K. Markeev. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 869–872.) Preliminary report on the construction of a radiospectrograph for the frequency band 45–90 Mc/s at the Scientific Research Institute for Terrestrial Magnetism, the Ionosphere and the Propagation of Radio Waves (N.I.Z.M.I.R.). Continuous tuning in this band is effected by ferrite variometers which are briefly described.

523.16 : 523.7 **1744**

Theory of Sporadic Radio Emission of the Sun.—V. V. Zheleznyakov. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 840–845.) The transformation of plasma waves into e.m. waves in an inhomogeneous plane-stratified medium is considered. The transformation coefficient, expressed as the square of the ratio of amplitudes of the e.m. and plasma waves, is about 3×10^{-7} for the solar corona.

523.16 : 523.7 **1745**

Radio Emission of Corona Condensations.—V. V. Vitkevich & M. I. Sigal. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 861–863.) Digest only. Results are presented of measurements at 10 and 50 cm λ, of the position of the centre of solar r.f. emission. The movement of the centre is explained by the presence of auxiliary sources which are connected with the 5 303-Å green line emission from the corona.

523.5 : 621.396.11 **1746**

The Theoretical Length Distribution of Ionized Meteor Trails.—V. R. Eshleman. (*J. atmos. terr. Phys.*, Feb. 1957, Vol. 10, No. 2, pp. 57–72.) The lengths are calculated from information on the production and radio detection of meteoric ionization, the mass distribution of shower and sporadic meteors, and the distribution of sporadic meteor radiants. The theory indicates that the length distribution of detected trails is independent of the sensitivity of the radar receiver and the power output of the transmitter.

523.5 : 621.396.11 **1747**

The Number Density of Meteor Trails Observable by the Forward Scattering of Radio Waves.—R. E. Pugh. (*Canad. J. Phys.*, Oct. 1956, Vol. 34, No. 10, pp. 997–1004.) A mathematical expression is derived for the trail distribution as a function of the position of the celestial region relative to transmitter and receiver. 'Observable' trails are those which produce pulses exceeding a given amplitude.

523.5 : 621.396.11 **1748**

The Spatial Distribution of Signal Sources at Meteoric Forward Scattering.—C. O. Hines & R. E. Pugh. (*Canad. J. Phys.*, Oct. 1956, Vol. 34, No. 10, pp. 1005–1015.) The contour charts of distribution obtained by a simplified method of analysis in which ellipsoids are replaced by cylinders [738 of 1956 (Hines)] are in good agreement with those computed by the more exact formulae given in *ibid.* pp. 997–1004 (Pugh). The influence of signal duration is examined and a comparison is also made with the earlier findings of Eshleman & Manning (1884 of 1954).

525.3 : 529.786 **1749**

The Atomic Clock and the Irregularity of the Earth's Rotation.—Stoyko. (See 1846.)

550.38 : 523.165 **1750**

Geomagnetic Variations in the Cosmic-Ray Disturbance of 23 February 1956.—P. L. Marsden, J. G. Wilson & D. C. Rose. (*J. atmos. terr. Phys.*, Feb. 1957, Vol. 10, No. 2, pp. 117–119.) The Leeds (England) data are compared with those from Ottawa, Durham (U.S.A.) and Chicago.

551.510.535 **7511**

Structure of the Lower Ionosphere and its Variations.—E. A. Lauter. (*Ber. dtsch. Wetterdienstes*, 1956, Vol. 4, No. 22, pp. 55–64.) The ionized region below the E-layer maximum at a height of about 100 km is discussed. 46 references.

551.510.535 **1752**

Remarks on the Meteorology of the Ionosphere.—K. Rawer. (*Ber. dtsch. Wetterdienstes*, 1956, Vol. 4, No. 22, pp. 83–84.) Brief remarks on (*a*) daily variation of the electron density distribution, (*b*) horizontal movements, (*c*) apparent vertical movements, and (*d*) turbulence in the upper ionosphere (above 100 km).

551.510.535 **1753**

Diffusion in the Ionosphere.—B. N. Gershman. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 720–731.) Diffusion of charged particles in a weakly ionized gas in the presence of molecules is considered, taking into account the presence of the geomagnetic field. Generalized diffusion equations are derived and the ambipolar approximation is discussed. The results are used to determine the 'lifetime' of inhomogeneities.

551.510.535 **1754**

Investigation of the Fine Structure of the Ionosphere by the Method of Frequency-Diversity Reception.—V. D. Gusev & S. F. Mirkotan. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 743–746.) Results are presented of a theoretical and experimental investigation of the frequency distribution of amplitude fading of a single signal reflected by the ionosphere. The vertical dimension of small-scale inhomogeneities is estimated.

551.510.535 **1755**

Phase Method of Recording Large Ionospheric Inhomogeneities.—V. D. Gusev & L. A. Drachev. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 747–751.) A vertical sounding method is described. Results for the F layer indicate a probable horizontal dimension of 135 km, assuming a constant velocity of 150 m/s.

551.510.535 **1756**

The Calculation of Ionospheric Electron Density Distributions.—J. M. Kelso. (*J. atmos. terr. Phys.*, Feb. 1957, Vol. 10, No. 2, pp. 103–109.) The method suggested includes the effect of the earth's magnetic field but is suitable for use when high-speed digital computers are unavailable or uneconomic.

551.510.535 **1757**

On the Determination of the Electron Density Distribution in the Ionospheric Regions from h'f Records.—A. K. Saha. (*Indian J. Phys.*, Sept. 1956, Vol. 30, No. 9, pp. 464–479.) Various known methods for determining the height distribution of electrons are discussed; for routine work, Ratcliffe's method (1292 of 1952) is quickest, though other methods are more accurate under particular conditions. For latitudes around that of Calcutta, the errors resulting from neglecting the magnetic field do not exceed those involved in the actual height measurement, with the apparatus used.

551.510.535 : 523.72 **1758**

Relation between the Ionization of the Ionosphere E Layer and Solar R.F. Radiation.—J. F. Denisse & M. R. Kundu. (*C. R. Acad. Sci., Paris*, 2nd Jan. 1957, Vol. 244, No. 1, pp. 45–47.) Analysis of observations indicates close correlation between the variations of the monthly mean values of f_0E and those of the solar radiation on 10·7 cm λ. The results suggest that the mechanisms of production of r.f. and X radiation from the sun are closely linked.

551.510.535 : 523.75 **1759**
: 621.396.11.029.45

Long-Path V.L.F.—Frequency Variations associated with the Solar Flare of 23 February 1956.—Allan, Crombie & Penton. (See 1889.)

551.510.535 : 523.78 **1760**

Recombination in the Ionosphere during an Eclipse.—D. R. Bates & M. R. C. McDowell. (*J. atmos. terr. Phys.*, Feb. 1957, Vol. 10, No. 2, pp. 96–102.) The change in electron density during a total eclipse is calculated on the assumption that there are two species of ion having different recombination coefficients. Various combinations of the coefficients and relative concentrations are investigated and the results are shown graphically.

551.510.535 : 621.396.11 **1761**

Note on a 'QL-QT' Transition Level in the Ionosphere.—B. Landmark & F. Lied. (*J. atmos. terr. Phys.*, Feb. 1957, Vol. 10, No. 2, pp. 114–116.) Experimental observations relating to Lepechinsky's hypothesis (see 3188 of 1956 and back reference) are discussed.

551.594.6 : 621.396.9 **1762**

Locating Atmospheric Disturbances by Synchronous Recording of Direction and Waveform.—G. Skeib. (*Ber. dtsch. Wetterdienstes*, 1956, Vol. 4, No. 22, pp 146–147.) Note of equipment which has been operating in Potsdam since 1953. It comprises a cathode-ray direction finder of the type described by Adcock and Clarke (2779 of 1947) and an atmospherics waveform recorder used in an investigation by Schindelhauer et al. (990 of 1952). Outputs from these two instruments are applied to a two-beam pulsed oscillograph displaying direction and waveform simultaneously.

523.16+551] : 621.396.96 **1763**

Les Applications du Radar à l'Astronomie et à la Météorologie. [Book Review]—van Bladel. (See 1769.)

LOCATION AND AIDS TO NAVIGATION

621.396.932 : 621.396.63 **1764**

The Radio Call [system] **for Ships in Distress.**—L. Chauveau. (*Rev. gén. Elect.*, Oct. 1956, Vol. 65, No. 10, pp. 561–568.) A survey of past and present automatic alarm systems.

621.396.96 **1765**

Choosing Radar Wavelengths.—R. F. Hansford & R. T. H. Collis. (*Wireless World*, April 1957, Vol. 63, No. 4, pp. 188–193.) The relative performances of 10- and 25-cm equipment for surveillance duties are discussed in relation to a medium-sized transport and a fighter aircraft. For the same aerial size the 10-cm radar gives better coverage and discrimination but no advantage on ground clutter. Attenuation in rain is not significant for either wavelength but back-scatter is worse at 10 cm. No general preference appears possible.

621.396.96 **1766**

Marine Radar Equipment.—Correction to 1085 of April: for 60-ft, please read 6-ft.

621.396.96 : 551.577/.578 **1767**

Radar Observations of Showers Suggesting a Coalescence Mechanism.—P. J. Feteris & B. J. Mason. (*Quart. J. R. met. Soc.*, Oct. 1956, Vol. 82, No. 354, pp. 446–451.) Observations using 3-cm and 10-cm equipment are reported and discussed.

621.396.963 : 621.397.3 **1768**

The P.P.I./Television Image Converter of the S.F.R. [Société Française Radio-Électrique].—R. Asté. (*Onde élect.*, Oct. 1956, Vol. 36, No. 355, pp. 822–828.) Outline description of a tube for direct electronic conversion of a p.p.i. radar image into a television signal.

621.396.96 : [523.16+551 **1769**

Les Applications du Radar à l'Astronomie et à la Météorologie. [Book Review]—J. van Bladel. Publishers: Gauthier-Villars, Paris, 1955, 147 pp., 1600 fr. (*Quart. J. R. met. Soc.*, Oct. 1956, Vol. 82, No. 354, pp. 550–551.) The main emphasis is on meteors and precipitating clouds. References are given to nearly 200 papers dated between 1945 and 1954.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.7 : 537.533 **1770**

The Measurement of Very Low Gas and Vapour Pressures.—F. Kirchner & H. Kirchner. (*Z. angew. Phys.*, Oct. 1956, Vol. 8, No. 10, pp. 478–481.) Technique is discussed for determining the pressure from the variation of the field emission of electrons from a clean W point as the point becomes coated with adsorbed gas molecules.

533.5 **1771**

Safety Assembly for Permanent-Vacuum Installations Connected to Pumps.—J. Conard. (*C. R. Acad. Sci., Paris*, 2nd Jan. 1957, Vol. 244, No. 1, pp. 52–54.)

533.215 **1772**

The Influence of Boundary Layers on Photoconduction.—F. Stöckmann. (*Z. Phys.*, 16th Oct. 1956, Vol. 146, No. 4, pp. 407–422.) Grain-surface depletion layers produced by adsorption of foreign matter have a marked influence on currents forced to pass through them. The expression for the photocurrent is of the same form as for photoconduction in a homogeneous volume, but there is an additional dependence on the dark current. A mechanism explaining the photocurrents in ZnO is discussed.

535.215 : 537.311.33 **1773**

Review of Papers Presented at the Meetings of the 'Photoelectric Phenomena in Semiconductors' Section [at the 8th All-Union Conference on Semiconductors, Leningrad, 14th–20th November, 1955].—S. M. Ryvkin. (*Uspekhi fiz. Nauk*, Oct. 1956, Vol. 60, No. 2, pp. 225–248.)

535.215 : 537.311.33 : 539.23 **1774**

Theory of Photoconductivity in Semiconductor Films.—R. L. Petritz. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1508–1516.) A model for photoconductive films is analysed in which it is assumed that the primary photoeffect is absorption of light and production of hole-electron pairs in the crystallites. The change in conductivity results from a change in majority-carrier density in the crystallites, and from reduction of intercrystalline potential barriers. The response to radiation, the noise, and the limit of sensitivity are analysed and measurements necessary for the evaluation of the parameters involved are discussed.

535.215 : 546.289 **1775**

Pulse Method of Investigating the Photoelectric Properties of a *p-n* Junction in Germanium.—Yu. I. Ukhanov. (*C. R. Acad. Sci. U.R.S.S.*, 21st Dec. 1956, Vol. 111, No. 6, pp. 1238–1241. In Russian.) The dependence of the light-pulse modulation of a h.f. pulse on the current amplitude (up to 2 A), carrier frequency (20 c/s–20 kc/s) and probe position was investigated. Results are tabulated and presented graphically, together with oscillograms. Electroluminescence was observed in a Ge diode.

535.215 : 546.817.221 **1776**

Spectral Distribution of the Photoeffect in Lead Sulphide.—H. U. Pfeiffer. (*Z. Naturf.*, Feb. 1956, Vol. 11a, No. 2, pp. 164–165.) Brief note on an experimental investigation of the effect of annealing conditions.

535.215.1 : 546.3 **1777**

The Effect of Mechanical Stresses on the Photoelectric Emission from Polycrystalline Metallic Substances.—R. Bernard, C. Guillaud, & R. Goutte. (*J. Phys. Radium*, Oct. 1956, Vol. 17, No. 10, pp. 866–871.) Experimental investigations show that emission increases under stress. The effect is reversible within the elastic range and irreversible beyond it.

535.37 **1778**

Phase Equilibria and Fluorescence in the System Zinc-Oxide/Boric-Oxide.—D. E. Harrison & F. A. Hummel. (*J. electrochem. Soc.*, Sept. 1956, Vol. 103, No. 9, pp. 491–498.) Detailed investigations were carried out on various forms of compounds. Experimental results are tabulated and discussed with reference to the findings of other authors.

535.376 **1779**

Secondary Waves of Electroluminescence.—C. H. Haake. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 117–123.) A simple model for charge polarization is developed describing the behaviour of secondary waves at varying temperature and frequency.

535.376 : 546.472.21 **1780**

The Electroluminescence of ZnS-Type Phosphors.—P. Zalm. (*Philips Res. Rep.*, Oct. & Dec. 1956, Vol. 11, Nos. 5 & 6, pp. 353–399 & 417–451.) Photoluminescence theories, particularly those concerning the nature of the fluorescence centres in ZnS, and methods of preparing electroluminescent powders are outlined. A qualitative model has been drawn up to explain the mechanism of electroluminescence. Observations show that a distinction is necessary between phosphors where excitation by an alternating field causes activator ionization and those where this fails to occur. The electroluminescence mechanism of hexagonal, Cu-activated, single ZnS crystals is essentially the same as for powders, and a relation is established between the orientation of the barrier layers at which light emission occurs and that of the crystal axes. The voltage characteristic of the emittance is due to a Mott-Schottky-type barrier. The case of crystals embedded in a dielectric is particularly examined. Experiments are analysed with regard to delayed light emission and temperature dependence of the emittance, and the energy efficiency of electroluminescent phosphors is studied. 62 references.

535.376 : 546.472.21 **1781**

High - Frequency - Induced Electroluminescence in ZnS.—G. G. Harman & R. L. Raybold. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1498–1499.) Note on measurements made over a frequency range 1 c/s–370 Mc/s.

535.376 : 546.472.21 **1782**

The Green-2 Band in the Ultraviolet Luminescence of Zinc Sulphide.—T. B. Tomlinson & E. A. D. White. (*J. Electronics*, Jan. 1957, Vol. 2, No. 4, pp. 404–405.) Experimental evidence suggests the green-2 band is not due to a new centre.

537.226/.227 **1783**

Structure and Phase Transitions of Ferroelectric Sodium-Lead Niobates and of other Sodium Niobate Type Ceramics.—M. H. Francombe & B. Lewis. (*J. Electronics*, Jan. 1957, Vol. 2, No. 4, pp. 387–403.) A structural and dielectric study shows that solid solutions of perovskite type are formed up to a limit of 35% replacement of sodium atoms by lead atoms and vacancies. A new ferroelectric tetragonal phase is introduced immediately below the Curie temperature. Partial substitution of niobium by tantalum lowers the ferroelectric transition temperatures. Multiple-cell effects can be ascribed to puckering of the niobium-oxygen framework and depend primarily on lattice spacing and packing.

537.226 : 546.431.824-31

Aging of the Dielectric Properties of Barium Titanate Ceramics.—K. W. Plessner. (*Proc. phys. Soc.*, 1st Dec. 1956, Vol. 69, No. 444B, pp. 1261–1268.) The permittivity and power factor decrease linearly with log *t* over periods up to several years from the time of cooling the material through the Curie point. The results are explained in terms of a very wide distribution of the activation energies governing the motion of domain walls.

537.226 : 621.315.61 **1785**

The Universal Significance of Ion Adsorption in Insulating Materials.—P. Böning. (*Z. angew. Phys.*, Oct. 1956, Vol. 8, No. 10, pp. 516–520.) A discussion illustrated by reference to mechanical, thermal and electrical processes in insulating materials.

537.226 : 621.372 **1786**

Realizability of a Prescribed Frequency Variation of Dielectric Constant.—R. J. Harrison. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, p. 367.) Modified Kronig-Kramers theory is used to derive the minimum attainable loss in a dielectric having an inverse-square dependence on frequency of real permittivity. With a large bandwidth the loss tangent becomes large over most of that band, and may limit application to cases requiring a constant electrical length of waveguide.

537.227 : 546.431.824-31 **1787**

Thermodynamical Theory of Ferroelectric Properties of Barium Titanate.—L. P. Kholodenko. (*Zh. eksp. teor. Fiz.*, Aug. 1956, Vol. 31, No. 2(8), pp. 244–253.) The nature of the phase transition from the non-ferroelectric to the ferroelectric phase is discussed and the effect of an electric field on the temperature of the transition is considered. The change in the dielectric constant near the Curie point and the piezomoduli of the piezoelectric effect induced by an electric field at temperatures near the Curie point are discussed.

537.228.1 : 548.0].001.4 (083.7) **1788**

I.R.E. Standards on Piezoelectric Crystals—the Piezoelectric Vibrator: Definitions and Methods of Measurement, 1957.—(*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, pp. 353–358.) Standard 57 I.R.E. 14.S1.

537.311.31 **1789**

Changes in the Electrical Conductivity of Metals on Fusion.—G. Darmois. (*C. R. Acad. Sci., Paris*, 7th Jan. 1957, Vol. 244, No. 2, pp. 174–176.)

537.311.31 : 538.632 **1790**

Electrical Resistivity and Hall Effect of Noble Metals at Very Low Temperatures.—T. Fukuroi & T. Ikeda. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. A*, June 1956, Vol. 8, No. 3, pp. 205–212.) Results are given of measurements on Au, Ag and Cu covering a temperature range of 1°–20° K.

537.311.33 + 535.37 **1791**

Inapplicability of the Fermi-Dirac Distribution to Electrons of Impurity Centres in Semiconductors and Crystal Phosphors.—S. I. Pekar. (*Zh. eksp. teor. Fiz.*, Aug. 1956, Vol. 31, No. 2(8), pp. 351–353.)

537.311.33 **1792**

Theory of Semiconductors at the 8th All-Union Conference on Semiconductors [Leningrad, 14th–20th November 1955].—V. L. Bonch-Bruevich. (*Uspekhi fiz. Nauk*, Oct. 1956, Vol. 60, No. 2, pp. 213–224.) Survey of papers presented at the conference. 37 references.

537.311.33 **1793**

The Chemical Bond in Semiconductors.—E. Mooser & W. B. Pearson. (*J. Electronics*, Jan. 1957, Vol. 2, No. 4, pp. 406–407.) A note on the transition from semiconducting to metallic behaviour of group-V elements.

537.311.33 **1794**

A Method of Evaluating Surface State Parameters from Conductance Measurements on Semiconductors.—G. G. E. Low. (*Proc. phys. Soc.*, 1st Dec. 1956, Vol. 69, No. 444B, pp. 1331–1334.) A theoretical treatment of the relationship between the various surface parameters involved in the determination of densities and cross-sections for majority-carrier capture.

537.311.33 **1795**

The Statistics of Divalent Impurity Centres in a Semiconductor.—C. H. Champness. (*Proc. phys. Soc.*, 1st Dec. 1956, Vol. 69, No. 444B, pp. 1335–1339.) The problem is treated by counting the states so as to allow for the double degeneracy due to spin, and applying the normal Fermi distribution function.

537.311.33 **1796**

Ionized Impurity Scattering in Nondegenerate Semiconductors.—N. Sclar. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1548–1558.) The problem is treated by the partial wave technique, using a square well for the attractive impurity and a square barrier for the repulsive impurity. For $ka \ll 1$, where k is the wave number of the charge carriers and a the range of the impurity potential, results for the variation of mobility with temperature and impurity concentration differ markedly from previous formulae, valid for $ka \gg 1$.

537.311.33 **1797**

Neutral Impurity Scattering in Semiconductors.—N. Sclar. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1559–1561.) A calculation by the partial wave technique is compared with that due to Erginsoy (*Phys. Rev.*, 15th Sept. 1950, Vol. 79, No. 6, pp. 1013–1014), and with a Born-approximation treatment.

537.311.33 **1798**

Anisotropy of the Hot-Electron Problem in Semiconductors with Spheroidal Energy Surfaces.—L. Gold. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1580–1584.) The energy gain for electrons in many-valley semiconductors is determined for any orientation of electric field. In particular for germanium and silicon values are given of the directional acceleratíve masses for both isotropic ($T \to 0$°K) and non-isotropic scattering.

537.311.33 **1799**

Statistics of Electrons and Holes in a Homopolar Semiconductor taking Account of the Interaction with Lattice Oscillations.—V. L. Bonch-Bruevich. (*Zh. eksp. teor. Fiz.*, Aug. 1956, Vol. 31, No. 2(8), pp. 254–260.) The stationary electron distribution is investigated, taking into account the electron-phonon interaction. The limiting cases of high and low temperatures are considered, and results indicate that owing to the interaction the electrical conductivity does not vanish at 0°K.

537.311.33 **1800**

Bipolar Diffusion of Current Carriers in the Presence of Deep Traps.—K. V. Tolpygo & E. I. Rashba. (*Zh. eksp. teor. Fiz.*, Aug. 1956, Vol. 31, No. 2(8), pp. 273–277.) A theoretical study taking into account the dependence of the minority-carrier lifetime on the degree of occupation of the traps is presented; criteria for the validity of a linear recombination law are established. A formula is deduced for the minority-carrier concentration distribution for the case of a nonlinear recombination law.

537.311.33 **1801**

Fabrication of Multiple Junctions in Semiconductors by Surface Melt and Diffusion in the Solid State.—K. Lehovec & A. Levitas. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 106–109.) Techniques are described suitable for preparation of structures with widths of intermediate layers accurately controlled over wide ranges. Close control is necessary over impurity concentration in preparing doubly doped crystals and in attachment of the base electrode contact.

537.311.33 : 537.533.9 **1802**

Measurement of Short Carrier Lifetimes.—G. K. Wertheim & W. M. Augustyniak. (*Rev. sci. Instrum.*, Dec. 1956, Vol. 27, No. 12, pp. 1062–1064.) Semiconductor carrier lifetimes as short as 10^{-8}s have been measured by bombarding the specimen with short pulses of 700-keV electrons from a Van de Graaff accelerator.

537.311.33 + 537.311.31] : 538.569.4 **1803**

Infrared Cyclotron Resonance in Bi, InSb, and InAs with High Pulsed Magnetic Fields.—R. J. Keyes, S. Zwerdling, S. Foner, H. H. Kolm & B. Lax. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1804–1805.) Measurement of the increase in effective electron mass with magnetic field strengths up to 300 000 gauss are reported.

537.311.33 : 538.69 **1804**

Magneto-band Effects in InAs and InSb in D.C. and High Pulsed Magnetic Fields.—S. Zwerdling, R. J. Keyes, S. Foner, H. H. Kolm & B. Lax. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1805–1807.) Measurements of the increase in the energy gap with magnetic field strengths up to 250 000 gauss are reported.

537.311.33 : 541.128 **1805**

Semiconductors as Catalysts for Chemical Reactions.—F. F. Volkenshtein. (*Uspekhi fiz. Nauk*, Oct. 1956, Vol. 60, No. 2, pp. 249–293.) A survey. 51 references, mostly to Russian literature.

537.311.33 : 546.24 **1806**

Study of the Recombination Process in Tellurium.—A. Pires de Carvalho. (*C. R. Acad. Sci., Paris*, 21st Jan. 1957, Vol. 244, No. 4, pp. 461–462.) The lifetime of minority carriers was measured using a photomagnetoelectric method. The observed temperature dependence can be explained on the assumption that the Auger effect plays a predominant part in the recombination.

537.311.33 : [546.28 + 546.289 **1807**

Density of States for Warped Spherical Energy Surfaces: Zeroth Order Solution for Holes in Silicon and Germanium.—L. Gold. (*J. Electronics*, Jan. 1957, Vol. 2, No. 4, pp. 323–329.) No exact solution appears possible but a zero-order calculation gives reasonable accuracy.

537.311.33 : [546.28 + 546.289] : 548.0 **1808**

Simplified Light Reflection Technique for Orientation of Germanium and Silicon Crystals.—R. D. Hancock & S. Edelman. (*Rev. sci. Instrum.*, Dec. 1956, Vol. 27, No. 12, pp. 1082–1083.)

537.311.33 : 546.28 : 669.046 **1809**

Precise Heat for growing Silicon Crystals.—E. T. Davis, W. B. Alden & F. H. Wyeth. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, pp. 164–167.) Induction heating of a crucible is controlled automatically within 0.25°C by a thermopile.

537.311.33 : 546.289 **1810**

Dependence of Lifetime of Non-equilibrium Charge Carriers in Germanium on Temperature and Composition.—E. I. Adirovich, G. M. Guro & V. F. Kuleshov. (*Zh. eksp. teor. Fiz.*, Aug.

1956, Vol. 31, No. 2(8), pp. 261–272.) Approximate formulae are derived for a semiconductor with a low trap concentration.

537.311.33 : 546.289 **1811**

Etching Experiments on Germanium Crystals.—H. A. Schell. (*Z. Metallkde*, Sept. 1956, Vol. 47, No. 9, pp. 614–620.) Etch patterns obtained with vertically pulled single crystals with various orientations are reproduced.

537.311.33 : 546.289 **1812**

The Isothermal Reverse Voltage/Current Characteristics of Small-Area Alloy Contacts on Germanium.—E. G. S. Paige. (*J. Electronics*, Jan. 1957, Vol. 2, No. 4, pp. 378–386.) At high currents the characteristics become independent of the type of junction. The results verify Gunn's theory (1030 of 1953) for the resistance of a small-area contact. The relation of the results to observations on point contacts is discussed.

537.311.33 : 546.289 **1813**

Effect of Structural Defects in Germanium on the Diffusion and Acceptor Behaviour of Copper.—C. S. Fuller & J. A. Ditzenberger. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 40–48.) Experiments indicate the slow attainment of acceptor equilibrium especially in Ge having low concentrations of dislocation and the identification of dislocations as the initial loci of acceptor Cu in Ge. Ideas on the mechanism of diffusion of Cu need revision. See also 169 of January (Tweet & Gallagher).

537.311.33 : 546.289 **1814**

Microdeterminations of Arsenic and Antimony in Metallic Germanium and Germanium Dioxide.—H. Goto & Y. Kakita. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. A*, June 1956, Vol. 8, No. 3, pp. 243–251.)

537.311.33 : 546.561-31 **1815**

Oxidation of Copper to Cu_2O and CuO (600°–1 000°C and 0·026–20·4 atm Oxygen).—D. W. Bridges, J. P. Baur, G. S. Baur & W. M. Fassell, Jr. (*J. electrochem. Soc.*, Sept. 1956, Vol. 103, No. 9, pp. 475–478.) Summary and analysis of results of oxidation tests carried out on oxygen-free, high-conductivity copper under the above conditions. 18 references.

537.311.33 : 546.681.19 **1816**

Energy Bands in Gallium Arsenide.—J. Callaway. (*J. Electronics*, Jan. 1957, Vol. 2, No. 4, pp. 330–340.) Electronic energy bands in GaAs are related to those of Ge by the use of second-order pertubation theory.

537.311.33 : 546.682.19 **1817**

Electrical Properties of *n*-Type InAs.—T. C. Harman, H. L. Goering & A. C. Beer. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1562–1564.) Measurements of Hall coefficient and resistivity on uncompensated specimens are reported. The energy gap was found to be 0·32 eV and electron mobility 30 000 cm²/V.sec, at room temperature.

537.311.33 : [546.682.86 + 546.682.19 **1818**

Determination of the Effective Masses in InSb and InAs by Measurement of the Differential Thermoelectric Force.—H. Weiss. (*Z. Naturf.*, Feb. 1956, Vol. 11a, No. 2, pp. 131–138.) Results of measurements on three *p*-type and five *n*-type specimens of InAs and on two specimens of *p*-type InSb indicate the following values: for InAs in the temperature range 500–800°K, $m_n = 0{\cdot}064m_o$, $m_p = 0{\cdot}33m_o$; for InSb at 333°K, $m_n = 0{\cdot}037m_o$, $m_p = 0{\cdot}18m_o$. The effective electron mass in InSb increases with temperature and reaches $0{\cdot}05m_0$ just below the melting point.

537.311.33 : 546.817.221 **1819**

Application of a Network Model to Semiconductors of the Lead Sulphide Type.—T. K. Rebane. (*Zh. eksp. teor. Fiz.*, Aug. 1956, Vol. 31, No. 2(8), pp. 353–354.) Coulson's network model (*Proc. phys. Soc.*, July 1954, Vol. 67, No. 415A, pp. 608–614) is applied to semiconductors of the type PbX, where X is S, Se or Te.

537.311.33 : 548.0 **1820**

Deformation Twinning in Materials of the *A*4 (Diamond) Crystal Structure.—A. T. Churchman, G. A. Geach & J. Winton. (*Proc. Roy. Soc. A*, 18th Dec. 1956, Vol. 238, No. 1213, pp. 194–203.) Continuation of investigation reported by Franks et al. (2321 of 1955). Deformation produced by hardness indentations in Si, Ge, InSb, GaSb and zinc blende are studied.

537.311.33 : 621.314.632 **1821**

Hole Injection at Metal/Semiconductor Point Contact.—D. Gerlich. (*Proc. phys. Soc.*, 1st Dec. 1956, Vol. 69, No. 444B, pp. 1350–1351.) An extension of the theory of Gunn (167 of 1955) to include the case of point contact with spherical geometry.

537.311.33 : 621.317.79 : 538.632 **1822**

A Pulse Method for Measurement of Hall Coefficient at Low Temperatures: some Results on Indium Antimonide.—Broom & Rose-Innes. (See 1862.)

537.533.8 : 546.3 **1823**

The Effect of Mechanical Stresses on the Secondary Electron Emission from Polycrystalline Metallic Substances.—F. Davoine & R. Bernard. (*J. Phys. Radium*, Oct. 1956, Vol. 17, No. 10, pp. 859–865.) Experiments on strips and wires under tension show an increase of up to 20% in the emission coefficient for Ni, Au and Mo. After annealing the coefficient returns to its original value. See also 1777 above.

538.22 **1824**

Magnetic Susceptibility of Dilute Cu Alloys at Low Temperatures.—F. T. Hedgcock. (*Phys. Rev.*, 15th Dec. 1956, Vol. 104, No. 6, pp. 1564–1567.) Results of measurements between room temperature and 4·2°K indicate an anomolous paramagnetism near the temperature of the observed resistance minimum.

538.221 **1825**

The Significance of Dislocation Density in the Theory of the Coercive Force of Recrystallized Materials.—M. Kersten. (*Z. angew. Phys.*, Oct. 1956, Vol. 8, No. 10, pp. 496–502.) Quantitative theory is based on the assumption that the domain walls are held fixed at dislocation sites but become curved on application of a magnetizing field (see also 501 of February). The coercive force represents the field strength at which the transition occurs from a reversible curvature of the walls to an irreversible Barkhausen jump. A simple formula is hence derived which gives values of the coercive force of magnetically soft recrystallized materials in good agreement with experimental values.

538.221 **1826**

Texture and Magnetization Curve of Silicon Iron.—D. Ganz & R. Brenner. (*Z. angew. Phys.*, Oct. 1956, Vol. 8, No. 10, pp. 502–505.) The deleterious effects on the magnetization curve of nonuniformity in orientation of the crystal grains are indicated.

538.221 **1827**

The Effect of the Induced Uniaxial Anisotropy on the Domain-Wall Displacements and Magnetic Behaviour of Ferromagnetic Cubic Solutions.—S. Taniguchi. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. A.*, June 1956, Vol. 8, No. 3, pp. 173–192.) The restoring force acting on domain walls is calculated as a function of wall displacement. The effects of domain-wall stabilization may account for certain properties of perminvars also commonly found in other cubic solid solutions. The properties of permalloys and the results of heat treatment are also discussed.

538.221 **1828**

The Density, Magnetic Properties, Young's Modulus, and ΔE-Effect, and their Changes due to Quenching in Ferromagnetic Iron-Aluminium Alloys: Part 2—Young's Modulus and the ΔE-Effect.—M. Yamamoto & S. Taniguchi. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. A.*, June 1956, Vol. 8, No. 3, pp. 193–204.) Results of measurements by the method of magnetostrictive vibration are presented. Part 1: 195 of January.

538.221 : 621.3.042.14 **1829**

Magnetic Effects of Compressional Stress at Low Field Intensities.—R. E. Fischell. (*Commun. & Electronics*, May 1956, No. 24, pp. 148–151. Discussion, p. 151.) Further report of investigations on various magnetic materials in the form of clamped laminations. For results of earlier tests, see 182 of 1956.

538.221 : 621.318.134 **1830**

Low-Frequency Dispersion of ρ and ϵ in Ferrites.—J. P. Suchet. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, p. 360.) Note on the dependence of surface-layer thickness on firing conditions mentioned by Van Uitert (*Proc. Inst. Radio Engrs*, Oct. 1956, Vol. 44, No. 10, pp. 1294–1303).

538.221 : 621.318.134 **1831**

Angles between Magnetic Spin Directions in Iron-Deficient Magnesium

Manganese Ferrites.—W. P. Osmond. (*Proc. phys. Soc.*, 1st Dec. 1956, Vol. 69, No. 444B, pp. 1319–1325.) The electrical and magnetic properties of thirteen square-loop ferrites are examined for evidence of the probable distribution of the various ions in the crystal lattice and of the relative strengths of their mutual interactions.; See also *Phil. Mag.*, Dec. 1956, Vol. 1, No. 12, pp. 1147–1156.

538.221 : 621.318.134 : 621.372.413 **1832**

Effects of Size on the Microwave Properties of Ferrite Rods, Disks, and Spheres.—J. O. Artman. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 92–98.) Retardation effects associated with the propagation of e.m. waves in the specimen are treated and results given for idealized cases of rods of infinite length and disks of infinite extent. An approximate solution for a sphere agrees qualitatively with experimental observations.

538.245 : 537.311.33 **1833**

Theory of Spontaneous Magnetization of Ferromagnetic Semiconductors in the Low-Temperature Region.—E. I. Kondorski, A. S. Pakhomov & T. Shiklosh. (*C. R. Acad. Sci. U.R.S.S.*, 11th Aug. 1956, Vol. 109, No. 5, pp. 931–934. In Russian.)

538.569.4 : 538.222 **1834**

Relaxation in the Spin System of Paramagnetic Salts.—L. J. Smits, H. E. Derksen, J. C. Verstelle & C. J. Gorter. (*Physica*, Sept. 1956, Vol. 22, No. 9, pp. 773–784. In English.) Paramagnetic absorption due to relaxation within the spin system was studied in various salts at 20·4°K. Three distinguishable types of behaviour were found and the results are discussed with reference to earlier theory.

539.23 **1835**

Electrical Resistances of Thin Metal Films before and after Artificial Aging by Heating.—R. B. Belser. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 109–116.) Experimental results and comments.

549.514.51 : 621.372.412.029.45 **1836**

Flexural-Mode Quartz Crystals as A.F. Resonators.—R. Bechmann & D. Hale. (*Electronic Ind. Tele-Tech*, Oct 1956, Vol. 15, No. 10, pp. 52–53 . . 94.) New techniques for growing Y-bar quartz crystals are outlined. Details of dimensions and operating characteristics for YX- and YZ-cut bars are given.

621.315.611 : 537.529 **1837**

Time Lags in the Intrinsic Electric Breakdown of Solid Dielectrics.—R. Cooper & D. T. Grossart. (*Proc. phys. Soc.*, 1st Dec. 1956, Vol. 69, No. 444B, pp. 1351–1353.) Measurements of time lag are described for various ionic crystals, polythene and polystyrene.

537.226/.227 **1838**

Ferroelektrika. [Book Review]—H. Sachse. Publishers: Springer, Berlin, 1956, 171 pp., DM 28. (*Z. angew. Phys.*, Oct. 1956, Vol. 8, No. 10, p. 520.) A monograph including a detailed treatment of ferroelectric titanates. Conditions for the occurrence of ferroelectricity in solids are discussed. Applications of ferroelectric materials are indicated, manufacturers are listed, and patent literature is included in the bibliography.

MATHEMATICS

517.5 **1839**

Some Theorems on Fourier Transforms and on the Coefficients of Typically Real Functions.—N. K. Artémiadis. (*C. R. Acad. Sci., Paris*, 28th Jan. 1957, Vol. 244, No. 5, pp. 544–547.)

517.521.4 **1840**

Note on a Method for Computing Infinite Integrals of Oscillatory Functions.—I. M. Longman. (*Proc. Camb. phil. Soc.*, Oct. 1956, Vol. 52, No. 4, pp. 764–768.) The method is based on Euler's transformation of slowly convergent alternating series.

517.566 : 621.396.812.3 **1841**

Properties of Random Functions.—D. S. Palmer. (*Proc. Camb. phil. Soc.*, Oct. 1956, Vol. 52, No. 4, pp. 672–686.) The relationships of the maxima, minima and zeros of two random functions of known correlations are investigated. Reference is made to the analyses of ionospheric reflection by Ratcliffe (3216 of 1954) and Briggs & Spencer (2945 of 1954). The frequency distributions of intervals between successive zeros and maxima, and of the lengths of intercepts by a horizontal line are considered; this has applications to the study of long-wave signal fading.

517.7 **1842**

Perturbation Solutions of the Ellipsoidal Wave Equation.—F. M. Arscott. (*Quart. J. Math.*, Sept. 1956, Vol. 7, No. 27, pp. 161–174.)

517.942 : 621.3.015.3 **1843**

Approximation to Transients by means of Laguerre Series.—J. W. Head. (*Proc. Camb. phil. Soc.*, Oct. 1956, Vol. 52, No. 4, pp. 640–651.) Tricomi's method as discussed by Ward (2163 of 1954) is investigated with special reference to conditions for convergence. The wider applications of Lin's iteration process for determining quadratic factors of polynomials is outlined.

518.61 **1844**

A Note on the Approximate Solution of the Equations of Poisson and Laplace by Finite-Difference Methods.—J. Eve & H. I. Scoins. (*Quart. J. Math.*, Sept. 1956, Vol. 7, No. 27, pp. 217–223.)

519.24 : 621.396.822 **1845**

The Statistical Description of Fluctuating Electrical Quantities.—G. Francini. (*Ricerca sci.*, Oct. 1956, Vol. 26, No. 10, pp. 2973–3004.) The principal methods of statistical analysis of frequency and amplitude distribution restricted to a single parameter are discussed. Problems of measurement are examined.

MEASUREMENTS AND TEST GEAR

529.786 : 525.3 **1846**

The Atomic Clock and the Irregularity of the Earth's Rotation.—N. Stoyko. (*C. R. Acad. Sci., Paris*, 2nd Jan. 1957, Vol. 244, No. 1, pp. 43–45.) The frequency deviations of standard-frequency transmissions based on the Cs resonator at the National Physical Laboratory are compared with figures derived on an astronomical basis in France. The results clearly indicate a seasonal variation of the rate of rotation of the earth.

539.32.082.4 **1847**

An Instrument for the Measurement of Elastic Moduli of Crystals.—K. S. Aleksandrov & O. V. Nosikov. (*Akust. Zh.*, July–Sept. 1956, Vol. 2, No. 3, pp. 244–247.) The principles are outlined of an instrument for the determination of the moduli by measurement of the velocity of propagation of longitudinal and transverse vibrations excited by ultrasonic pulses.

621.3.08+621-52 **1848**

Some Principles of Measurement and Control.—J. F. Coales. (*J. sci. Instrum.*, Dec. 1956, Vol. 33, No. 12, pp. 457–464.) The principles of the design of measuring systems are discussed in relation to the limitations imposed by inertia, damping and the disturbing effects on the measured quantities. The simple theory of linear control systems is developed and it is shown that they differ from measuring systems only in the magnitude of the required output.

621.3.08 : 621.3.018.78 : 534.86 **1849**

Correlation Method of Measuring the Distortion Coefficient of Transmitted Signals.—M. A. Sapozhkov. (*Akust. Zh.*, July–Sept. 1956, Vol. 2, No. 3, pp. 279–284.) The method of measuring the generalized coefficient of distortion and interference is based on the determination of the input-output correlation.

621.3.083.4 : 621.317.72 **1850**

Transistor Null Detector has High Sensitivity.—C. D. Todd. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, pp. 184–185.) A four-stage a.f. amplifier and detector are built into a compact case with a microammeter. Sensitivities from 20 μV to 2 V are achieved.

621.317.32 **1851**

The Measurement of Periodic High Voltages by Capacitor Currents.—J. Lagasse & G. Giralt. (*C. R. Acad. Sci., Paris*, 21st Jan. 1957, Vol. 244, No. 4, pp. 442–444.) The method of determining peak voltage values by measuring the rectified current through a standard capacitor is discussed; typical values of the currents to be rectified are between 10 and 50 μA. An arrangement using a pair of Si rectifiers in parallel opposition can be designed to give very low errors.

621.317.32.029.4 **1852**

Modulation Method of Measuring Small Electric Voltages in the Audio

Frequency Region.—D. K. Balabukha, L. L. Myasnikov & E. N. Plotnikova. (*Akust. Zh.*, July–Sept. 1956, Vol. 2, No. 3, pp. 248–254.) The principles of an instrument for the measurement of a.f. voltages of the order of a few microvolts in the frequency range 200 c/s–20 kc/s are discussed and some practical details are given. The a.f. voltage was modulated at 24 c/s by a periodically varying capacitance in the input stage of an a.f. amplifier. Various detectors were used.

621.317.342.012 **1853**

An Instrument for the Static Measurement and Oscillographic Representation of Phase [-angle] **or Phase-Delay Curves.**—H. Schönfelder. (*Frequenz*, Oct. 1956, Vol. 10, No. 10, pp. 309–318.) A comparison of methods of measurement and their application shows that group-delay indication is the most useful in the majority of cases. A circuit is described which is suitable for measuring phase angle, phase delay and signal amplitude, their variation with frequency being shown in the form of oscillograms.

621.317.361 : 621.385.029.64 **1854**

Measurement of the Spectral Line Width of a Klystron Oscillator at a Wavelength of 3·2 cm.—V. S. Troitski & V. V. Khrulev. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 831–837.) Bershtein's method (see 1696 above) was used. The fundamental line width was 0·3–0·8 c/s. The amplitude and frequency fluctuation spectra in the 2–25-Mc/s band were also investigated.

621.317.444 **1855**

Magnetic Fluxmeter for Measuring in Three Dimensions.—M. Müller. (*Elect. Commun.*, Sept. 1956, Vol. 33, No. 3, pp. 220–223.) A rotating-probe instrument is described capable of measuring the three components of narrow cylindrical magnetic fields required for the focusing of electron beams.

621.317.7 : 621.374.3 : 621.397.62 **1856**

A Spot and Graticule [pattern] **Generator for Laboratory Use.**—E. E. Hücking. (*Elektronische Rundschau*, Oct. 1956, Vol. 10, No. 10, pp. 270–274.) The instrument described generates pulses of 0·1 μs duration which are used to form either a spot or a graticule raster for television testing.

621.317.725 : 621.313.32.001.4 **1857**

A Valve Voltmeter for Synchro Testing.—D. L. Davies. (*Electronic Engng*, Feb. 1957, Vol. 29, No. 348, pp. 52–57.) The apparatus detects synchro null positions and measures total residue signal, separating quadrature fundamental from harmonics and noise. Circuit diagrams are given.

621.317.725 : 621.385 **1858**

A Phase-Sensitive Valve Voltmeter.—R. Kitai. (*Electronic Radio Engr*, April 1957, Vol. 34, No. 4, pp. 124–128.) Details of its design and characteristics.

621.317.733 **1859**

A Simple Method for the Measurement of High Resistance Values.—A. E. Hawkins. (*J. sci. Instrum.*, Dec. 1956, Vol. 33, No. 12, p. 486.) A modified Wheatstone-bridge network is described for resistance measurement up to $10^9\ \Omega$. Accuracy is within $\pm 2\%$.

621.317.733 : 621.316.86 **1860**

A Simple Direct-Reading Thermistor Bridge.—J. Swift. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1956, Vol. 17, No. 10, pp. 341–345; *J. Brit. Instn Radio Engrs*, March 1957, Vol. 17, No. 3, pp. 155–159.) The bridge described is suitable for accurate r.f. power measurements in the range approximately 10 μW–1mW. Ambient temperature compensation and facilities for battery operation are provided.

621.317.733.029.3 **1861**

An A.C. Kelvin Bridge for the Audio-Frequency Range.—B. L. Dunfee. (*Commun. & Electronics*, May 1956, No. 24, pp. 123–127. Discussion, pp. 127–128.) Details are given of a four-terminal resistor adjustable from 0·1 to 0·05 Ω designed for use as an a.c. reference standard with the Kelvin bridge described.

621.317.79 : 538.632 : 537.311.33 **1862**

A Pulse Method for Measurement of Hall Coefficient at Low Temperatures: some Results on Indium Antimonide.—R. F. Broom & A. C. Rose-Innes. (*Proc. phys. Soc.*, 1st Dec. 1956, Vol. 69, No. 444B, pp. 1269–1275, plate.) A description of a method suitable for use at liquid-helium temperatures with high-resistance semiconductors having a Hall mobility not less than $2cm^2/V.sec$. The activation energy is calculated from the variation of Hall coefficient with temperature. The results are in agreement with the equation proposed by Pearson & Bardeen (*Phys. Rev.*, 1st March, 1949, Vol. 75, No. 5, pp. 865–883) relating activation energy with impurity concentration.

621.317.794 : 621.396.822 **1863**

Stability Requirements and Calibration of Radiometers when Measuring Small Noise Powers.—J. C. Greene. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, pp. 359–360.) Note on a modification of Dicke's system (475 of 1947).

621.317.794 : 621.396.822 **1864**

A Comparison of Two Radiometer Circuits.—D. G. Tucker: M. H. Graham: S. J. Goldstein, Jr. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, pp. 365–366.) Comments on 535 of 1956 (Goldstein) and author's reply.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.77 : 621.383.4 : 621.314.7 **1865**

A Simple Direction-Sensitive Phototransistor Circuit for Use in Optical Pulse-Counting Systems.—W. T. Bane & D. L. A. Barber. (*J. sci. Instrum.*, Dec. 1956, Vol. 33, No. 12, pp. 483–486.) An output pulse is directed to one of two lines according to the direction of rotation of a serrated disk interrupting a beam of light falling on two photocells.

534.1-8 : 620.179.1 **1866**

Step-Function Pulse Technique for Ultrasonic Measurement.—(*Electronic Engng*, Feb. 1957, Vol. 29, No. 348, p. 77.) A basically new technique for thickness measurement and flaw detection whereby sections between 0·10 in. and 0·25 in. can be directly inspected.

621-52 : 681.142 **1867**

Systems of Automatic Regulation Involving Digital Computers.—Ya. Z. Tsypkin. (*Avtomatika i Telemekhanika*, Aug. 1956, Vol. 17, No. 8, pp. 665–679.) A review.

621.317.39 : 531.7 : 621.374.32 **1868**

The Automatic Measurement and Recording of Quasi-static Expansions by means of String Extensometers and Electronic Counters used as Frequency and Time-Interval Meters.—C. Rohrbach. (*Z. Ver. dtsch. Ing.*, 11th Sept. 1956, Vol. 98, No. 26, pp. 1541–1548.)

621.362 : 621.385.2 **1869**

Thermionic Diodes as Energy Converters.—Moss. (See 1983.)

621.383 : 621.373.5 : 616-1 **1870**

Sensory Aid Defines Lights and Marks.—C. R. Hurtig. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, pp. 162–163.) A miniature device which enables the blind to locate a meter needle or other light or dark object. An audible note produced by a transistor relaxation oscillator is varied by a photocell.

621.384 **1871**

A Thermal-Ion Source with Extremely Low Consumption of Material.—H. Hintenberger & C. Lang. (*Z. Naturf.*, Feb. 1956, Vol. 11a, No. 2, pp. 167–168.) The construction of an ionization source is described.

621.384.6 **1872**

Particle Accelerators and Their Applications.—D. R. Chick & C. W. Miller. (*Brit. Commun. Electronics*, Oct. & Nov. 1956, Vol. 3, Nos. 10 & 11, pp. 539–545 & 596–601.) A survey of existing types and an outline of present and future applications. 33 references.

621.384.6 **1873**

All-Union Conference on Physics of High-Energy Particles [Moscow, 14th–22nd May 1956] **(Second Section).**—P. O. Chechik. (*Radiotekhnika i Elektronika*, July 1956, Vol. 1, No. 7, pp. 1014–1023.) Abstracts and references of papers presented at the conference. Texts of the following 10 papers are printed in full (*ibid.*, pp. 893–1013):

Some Properties and Basic Data of the High-Frequency System of the 6-metre Phasotron.—A. L. Mints, I. Kh. Nevyazhski & B. I. Polyakov (pp. 893–902).

Transverse Oscillations in the Dee System of the Phasotron.—A. D. Vlasov (pp. 903–909).

System Linking the Frequency of the Accelerating Field with the Field Strength of the Magnetic Field of the 10^9-eV Synchrophasotron.—A. L. Mints, S. M. Rubchinski, M. M. Veisbein, F. A. Vodop'yanov, A. A.

Kuz'min & V. A. Uvarov (pp. 910–927).

Primary Oscillator in System Linking the Frequency of the Accelerating Field with the Field Strength of the Magnetic Field of the 10^9-eV Synchrophasotron.—V. A. Vodop'yanov (pp. 928–939).

Accelerating Elements of Synchrophasotrons and Fundamental Problems of Supplying Them with High-Frequency Voltage.—Yu. M. Lebedev-Krasin (pp. 940–953).

Application of Ferrite-Cored Inductors in the High-Power High-Frequency Stages of the Synchrophasotron.—I. Kh. Nevyazhski, G. M. Drabkin, V. F. Trubetskoi & A. S. Temkin (pp. 954–964).

Automatic Tuning of the Final Stage of the High-Frequency Oscillator in the 10^9-eV Synchrophasotron.—G. M. Drabkin, L. M. Gurevich, B. M. Gutner & N. K. Kaminski (pp. 965–973).

Control Systems for the Injection and Particle Acceleration Processes in the Synchrophasotron.—A. L. Mints, S. M. Rubchinski, M. M. Veisbein & A. A. Vasil'ev (pp. 974–985).

Measurement of the Instantaneous Frequency of the Frequency-Modulated Oscillations.—S. M. Rubchinski, A. A. Vasil'ev, V. F. Kuz'min & N. I. Fedorenko (pp. 986–1000).

Measurement of the Instantaneous Values of the Intensity of the Varying Magnetic Fields.—S. M. Rubchinski, M. P. Zel'dovich & S. S. Kurochkin (pp. 1001–1013).

621.384.6 **1874**

Gyroscopic Analogies for Circular Accelerators.—F. Fer. (*C. R. Acad. Sci., Paris*, 28th Jan. 1957, Vol. 244, No. 5, pp. 566–568.) Analogue techniques for investigating the trajectories of particles in a circular accelerator are discussed.

621.384.6 **1875**

Fixed-Field Alternating-Gradient Accelerators.—L. J. Laslett. (*Science*, 26th Oct. 1956, Vol. 124, No. 3226, pp. 781–787.) Structures of two types are surveyed, one using radial and the other spiral sectors. 23 references.

621.385.833 **1876**

A Mathematical Field Model for a Permanent-Magnet Unipotential [electron] **Lens.**—F. Lenz. (*Z. angew. Phys.*, Oct. 1956, Vol. 8, No. 10, pp. 492–496.) The magnetic 'unipotential' lens is defined, by analogy with the e.s. unipotential lens, as one in which the integral of the magnetic induction along the axis is zero. Analysis is presented for rotationally symmetrical arrangements. An expression is given for the field distribution which permits a solution in closed form to be obtained for the differential equation for the paraxial electron trajectories.

621.385.833.032.2 : 621.319.47 **1877**

Potential in Doubly Curved Condensers.—R. Albrecht. (*Z. Naturf.*, Feb. 1956, Vol. 11a, No. 2, pp. 156–163.) The potential distribution between a pair of doubly curved electrodes for use in an electron-optical system is calculated; the converse problem of calculating the constants of the electrodes when the field is given, is also considered.

621.397.3 : 681.142 **1878**

Reading by Electronics.—(*Wireless World*, April 1957, Vol. 63, No. 4, pp. 173–175.) A note on automatic character recognition using logical gate circuits, and an outline description of a machine with a recognition rate of 120 characters per second.

77 : 537.2 **1879**

Xerography.—W. D. Oliphant. (*Research, Lond.*, Nov. 1956, Vol. 9, No. 11, pp. 436–442.) "Xerography is a photographic process in which image reproduction is controlled by electrostatic and triboelectric phenomena. The fundamentals of the technique are outlined here and its applications discussed."

PROPAGATION OF WAVES

538.566 : 537.56 **1880**

Propagation of Strong Electromagnetic Waves in Plasma.—A. V. Gurevich. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 704–719.) The effects of the change in the energy of electrons in the plasma (ionosphere) produced by an e.m. wave are considered theoretically. Expressions are derived, and analysed, for the absorption and the phase change of the wave in the plasma.

538.566 : 537.56 **1881**

Wave Propagation in the Plasma between Two Perfectly Conducting Planes in the Direction of an Applied Magnetic Field.—W. O. Schumann. (*Z. angew. Phys.*, Oct. 1956, Vol. 8, No. 10, pp. 482–485.) Extension of analysis presented previously (e.g. 717 of 1951). In general, for the system discussed, there are three frequency ranges for which the propagation constant is imaginary. When the plasma moves in the direction of the magnetic field, growing e.m. waves are possible in these ranges.

538.566 : 537.56 **1882**

The Influence of a Constant Magnetic Field on the Resonance Effect, Observed at the Reflection of an Electromagnetic Wave by an Inhomogeneous Plasma.—N. G. Denisov. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 732–738.) Theoretical paper. Results indicate that for ionospheric conditions the effect of the resonance region on the reflection of radio waves is negligible. The influence of plasma waves is also considered.

538.566.2 **1883**

Propagation of Modulated Waves in a Medium with Pronounced Dispersion.—S. I. Averkov & V. Ya. Ryadov. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 739–742.) Brief description of apparatus and results of an experimental investigation of the conversion of a periodic amplitude modulation into frequency modulation due to the propagation of an e.m. wave through a dispersive medium.

538.566.2 **1884**

Theory of Scattering of Radio Waves at Moving Inhomogeneities.—G. S. Gorelik. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 695–703.) Discussion on the basis of the turbulent diffusion theory is presented. The time function of autocorrelation of the scattered field is related to the statistical characteristics of the motion of the inhomogeneities.

538.566.2 **1885**

Multiple Small-Angle Scattering of Waves by an Inhomogeneous Medium.—P. Gosar. (*Nuovo Cim.*, 1st Oct. 1956, Vol. 4, No. 4, pp. 688–702. In English.) Theory is presented for propagation in a medium with very small fluctuations of the refractive index, e.g. radio propagation in a turbulent atmosphere. The analysis starts from the scalar wave equation and makes use of an autocorrelation function.

621.396.11 **1886**

British Research into Radio Propagation by Tropospheric Scatter.—(*Engineer, Lond.*, 26th Oct. 1956, Vol. 202, No. 5257, p. 595.) Experiments have been made using a 30-ft-diameter fixed radiator fed by a horn mounted on a trailer carrying a 500-W transmitter operating at a frequency of 858 Mc/s. Plans for further tests on a multi-channel link between London and Newcastle are briefly indicated; a transmitter power of 10 kW is to be used.

621.396.11 : 551.510.535 **1887**

Note on a 'QL-QT' Transition Level in the Ionosphere.—Landmark & Lied. (See 1761.)

621.396.11 : 551.510.535 : 621.317.328 **1888**

The Measurement of the Scattering Coefficient in the Back-Scattering of Short-Wave Telegraphy Signals.—B. Beckmann & L. Vogt. (*Nachrichtentech. Z.*, Oct. 1956, Vol. 9, No. 10, pp. 441–448.) The influence of aerial radiation patterns on the values of field strength near the transmitter and the receiver is investigated. The correlation between these values is established by determining the scattering coefficient from measurements of the elevation angle for the maximum back-scatter signal. The method of indication was that adopted in previous tests (896 of 1956).

621.396.11.029.45 : 551.510.535 : 523.75 **1889**

Long-Path V.L.F.—Frequency Variations associated with the Solar Flare of 23 February 1956.—A. H. Allan, D. D. Crombie & W. A. Penton. (*J. atmos. terr. Phys.*, Feb. 1957, Vol. 10, No. 2, pp. 110–113.) The frequency and phase variations of Rugby (16 kc/s) received in N. Zealand during the great solar flare are compared with the changes during a normal flare. The difference is attributed to the cosmic-ray increase which accompanied the great flare.

621.396.11.029.6 **1890**

Propagation Tests at Frequencies of 250, 500 and 1 000 Mc/s.—F. Carassa. (*Alta Frequenza*, Oct. 1956, Vol. 25, No. 5, pp. 378–390.) Summary and analysis of results obtained during the period 1951–1952 over the 189-km path in Northern Italy for which 1-kMc/s tests had earlier been reported [see 3522 of 1956 (Vecchiacchi)].

621.396.11.029.6 : [621.396.41 + 621.397.26] **1891**

Television and Telephone Radio Relay System in Denmark.—Nielsen, Christensen, Sterndorff & Gudmandsen. (See 1908.)

RECEPTION

621.396.62 **1892**

Modern Means of Radio Reception.—C. Reuber. (*Elektrotech. Z., Edn B*, 21st Oct. 1956, Vol. 8, No. 10, pp. 361–366.) A description of the receiving and a.f. distribution equipment used for the monitoring services of the German Federal Government Information Department.

621.396.62 : 621.314.7 **1893**

A Passive Transistor Receiver.—H. E. Hollmann. (*Frequenz*, Oct. 1956, Vol. 10, No. 10, pp. 329–331.) The circuit outlined draws its power from the r.f. energy of a local transmitter and is capable of driving a loudspeaker.

621.396.62 : 621.376.3 **1894**

A Stable F.M. Receiver with Preset Tuning.—G. S. Robinson. (*Electronic Engng*, Feb. 1957, Vol. 29, No. 348, pp. 88–91.) A detailed description of circuits and construction. A crystal-controlled local oscillator is used.

621.396.621 :621.398 **1895**

Remote-Control Receiver.—E. Bohr. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, p. 149.) Description of the circuit of a lightweight two-transistor receiver operating on 27 Mc/s, the output of which operates a conventional relay.

621.396.621.54 : 621.314.7 **1896**

The Application of Transistors to A.M. Broadcast Receivers.—B. F. C. Cooper. (*Proc. Instn Radio Engrs, Aust.*, Oct. 1956, Vol. 17, No. 10, pp. 331–340 ; *J. Brit. Instn Radio Engrs*, Feb. 1957, Vol. 17, No. 2, pp. 95–106.) An experimental superheterodyne receiver using five *n-p-n* transistors is described and the performance analysed against that of a conventional four-valve portable receiver as a target.

621.396.621.54 :621.372.54 **1897**

Some Aspects of Intermediate-Frequency Filtering in a Receiver.—Carteron. (See 1691.)

621.396.82 : 621.376.2 **1898**

Some Aspects of Detection from the Point of View of Information.—J. Cauchois. (*Ann. Radioélect.*, Oct. 1956, Vol. 11, No. 46, pp. 308–316.) Brief survey of detection theory applicable to a.m., with particular reference to synchronous methods. 24 references.

621.396.822 : 621.317.794 **1899**

Stability Requirements and Calibration of Radiometers when Measuring Small Noise Powers.—Greene. (See 1863.)

621.396.822 : 621.317.794 **1900**

A Comparison of Two Radiometer Circuits.—Tucker : Graham : Goldstein. (See 1864.)

STATIONS AND COMMUNICATION SYSTEMS

621.376.22.029.64 : 621.372.8 **1901**

Amplitude Modulation of Microwaves by Tunable Transmission Waveguide Filters.—Potok & Barbour. (See 1652.)

621.39.001.11 **1902**

Hearing and Seeing.—C. Cherry. (*Wireless World*, April 1957, Vol. 63, No. 4, pp. 164–168.) The reduction of redundancy in information channels becomes increasingly important. To achieve this without increasing the probability of errors, it is necessary to have a more complete understanding of the fundamental problems of human perception.

621.396.2 :621.376.2 **1903**

Reception of a Doubly Modulated Signal.—M. Anastassiadès. (*C. R. Acad. Sci., Paris*, 7th Jan. 1957, Vol. 244, No. 2, pp. 183–184.) A radio system is proposed in which the carrier (e.g. 50 Mc/s) is modulated by an i.f. (e.g. 1 Mc/s) as well as by the a.f. signal. No frequency changer is needed at the receiver ; a Si diode is used as a simple detector, its slope being about twice the conversion slope when used as a mixer, the comparison being made on the basis of calculations presented by Herold & Malter (797 of 1944). The i.f. strength would be comparatively low, because of the absence of the local oscillator. Bandwidth considerations indicate that such a system would not be practical at frequencies below u.h.f.

621.396.41 **1904**

A 72-Channel Radio System for Toll Telephone Service.—M. C. Harp & M. H. Kebby. (*Commun. & Electronics*, May 1956, No. 24, pp. 113–119. Discussion, p. 119.) Description of the Type-72B system for operation in the 900-Mc/s band.

621.396.41 **1905**

Description and Technical Details of the Semi-fixed Pulse Multiplex Installation Type MX.620 for 12 or 24 [telephone] **Channels.**—R. Casse & L. Masliah. (*Ann. Radioélect.*, Oct. 1956, Vol. 11, No. 46, pp. 339–358.)

621.396.41 : 621.317.34 **1906**

Crosstalk Measuring Equipment for [f.m.] **Multichannel Radio Links.**—G. De Lotto. (*Alta Frequenza*, Oct. 1956, Vol. 25, No. 5, pp. 411–425.) The equipment described produces white-noise modulation, and measurements are directly applicable to operational conditions as covered by C.C.I.F. recommendations.

621.396.41 : 621.374.4 **1907**

Reference Generator for S.S.B. Systems.—Jacob. (See 1705.)

621.396.41 + 621.397.26] : 621.396.11.029.6 **1908**

Television and Telephone Radio Relay System in Denmark.—B. Nielsen, P. Christensen, P. Sterndorff & P. Gudmandsen. (*Teleteknik, Copenhagen*, Oct. 1956, Vol. 7, No. 3, pp. 113–156.) A detailed description is given of the network, the station installations and the operating facilities. Several unattended stations are operated by remote control from two attended stations. Preparatory measurements on two oversea paths of lengths 54 and 82 km respectively are reported; wavelengths of 6·4 and 17·0 cm were used simultaneously.

621.396.41.029.6 : 621.396.822.1 **1909**

The Problem of Crosstalk in Frequency-Modulated Radio Relay Equipment for Small Numbers of Channels.—I. Wigdorovits. (*Brown Boveri Rev.*, Sept. 1956, Vol. 43, No. 9, pp. 384–393.) A combined graphical and numerical method of calculating the crosstalk noise at the output terminals of a frequency-division multiplex link is described with the aid of an example.

621.396.5 : 534.78 **1910**

Instantaneous Speech Compressor.—Rutherford. (See 1632.)

621.396.65 : 621.376.3 : 621.397.8 **1911**

The Effect of Group Delay Variations on the Video Pass Band of a Radio Link.—I. S. Stojanovic. (*Ann. Radioélect.*, Oct. 1956, Vol. 11, No. 46, pp. 293–301.) The distortions introduced by time delay variations are analysed to obtain a general formula for calculating the signal amplitude.

621.396.712.2 : 621.396.664 **1912**

Automatic Programming in Small A.M. Stations.—E. C. Miller. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, pp. 146–148.) 20-c/s tone superimposed on a magnetic tape recording controls the operation of the reproducer and associated record player.

SUBSIDIARY APPARATUS

621-52 + 621.3.08 **1913**

Some Principles of Measurement and Control.—Coales. (See 1848.)

621.3.087.6 **1914**

Pen Motor for Rectilinear Recording.—F. Massa & E. A. Massa. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, pp. 159–161.) Describes a recorder-pen driven by a moving coil through a mechanical linkage. Critical damping, and freedom from ink-spattering and pen-whip at writing speeds up to 200 c/s are achieved.

621.316.722.1 **1915**

Barretter-Bridge-Circuit Voltage Stabilizer.—G. Szabó. (*Z. angew. Phys.*, Oct. 1956, Vol. 8, No. 10, pp. 512–516.) Conditions for optimum power consumption, temperature compensation and stability are investigated for a bridge comprising two ohmic resistances and two tungsten-filament lamps.

621.35 : 539.169 **1916**

Nuclear Batteries.—J. R. Milliron. (*Elect. Mfg*, Nov. 1955, Vol. 56, No. 5, pp. 125–131.) The principles of operation of the contact-potential, solid-dielectric and solid-state types of cell are described and details of some commercial products, including the solar battery, are given.

TELEVISION AND PHOTOTELEGRAPHY

621.397.24 : [621.372.54 + 621.372.553 **1917**

Filters and Delay Equalizers for Television Transmission on Cables.—H. Keil. (*Nachrichtentech. Z.*, Oct. 1956, Vol. 9, No. 10, pp. 469–475.) The solution of network design problems arising from s.s.b. television transmissions on coaxial cables is discussed.

621.397.3 : 621.396.963 **1918**

The P.P.I./Television Image Converter of the S.F.R. [Société Française Radio-Électrique].—Asté. (See 1768.)

621.397.5 : 535.623 **1919**

Perceptions of Colours in Projected and Televised Pictures.—D. A. MacAdam. (*J. Soc. Mot. Pict. Telev. Engrs*, Sept. 1956, Vol. 65, No. 9, pp. 455–469. Discussion, p. 469.) A special colorimetric method was used to investigate the chromatic adaptation of the eye to artificial and daylight illumination. The test results are analysed in detail and their relevance to satisfactory reproduction of colour television is discussed. 23 references.

621.397.5 : 535.623 : 621.395.625.3 **1920**

Colour TV on Tape.—H. R. L. Lamont. (*Wireless World*, April 1957, Vol. 63, No. 4, pp. 183–187.) Description of a R.C.A. video recorder. See 1592 of May (Olson et al.).

621.397.5 : 778.5 **1921**

A New Telerecording Equipment. (*Electronic Engng*, Feb. 1957, Vol. 29, No. 348, p. 70.) Features of the Marconi Type-BD679 equipment are briefly described with a photograph.

621.397.6 : 535.623 **1922**

Some Problems in a Band-Sharing Colour Television System.—A. V. Lord. (*J. Telev. Soc.*, Oct./Dec. 1956, Vol. 8, No. 4, pp. 130–141.) The discussion of distortion effects and remedies is restricted to the N.T.S.C. type of system.

621.397.61 **1923**

Vision Transmitter Design.—V. J. Cooper. (*J. Telev. Soc.*, Oct./Dec. 1956, Vol. 8, No. 4, pp. 149–162.) The techniques described refer particularly to bands III and IV and to colour-television requirements.

621.397.61 **1924**

Implications of Phase Precompensation in a Television Transmitter on the Shape of the Radiated Signal.—A. van Weel. (*J. Brit. Instn Radio Engrs*, Feb. 1957, Vol. 17, No. 2, pp. 129–134.) Phase errors in the receiver which produce smears following black-to-white transitions can be compensated by an overshoot introduced by a phase-precompensating network in the video-frequency section of the transmitter, provided that the modulation characteristic is linear. Some loss of signal power may result.

621.397.61 **1925**

Portable TV Station for Remote Pickups.—L. E. Flory, G. W. Gray, J. M. Morgan & W. S. Pike. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, pp. 170–177.) Describes a complete television outside broadcasting unit for carriage on a man's back. The equipment, using transistors, has a range of 1 mile and includes monitoring facilities and power supplies. See also 1599 of May.

621.397.61 : 535.623 **1926**

Colour TV System uses Flying-Spot Scan.—H. Mate. (*Electronics*, 1st Feb. 1957, Vol. 30, No. 2, pp. 138–142.) Light is projected on to the scene to be televised from a raster on a c.r. tube in a conventional television-camera housing. Reflected light is picked up by colour-sensitive photoelectric cells.

621.397.61 : 621.397.7(43) **1927**

Südwestfunk Television Transmitter Technique.—(*Tech. Hausmitt. NordwDtsch. Rdfunks*, 1956, Vol. 8, Nos. 3/4, pp. 41–89.) Eight papers give details of aerial and transmitter installations including frequency-conversion relay stations. The use of helicopters in measuring field strengths and in selecting aerial location and height is described. For details of Südwestfunk studios, see 2895 of 1956.

621.397.61 : 621.397.7 : 535.623 **1928**

Compact Plug-In Colour Video Equipment.—W. B. Whalley. (*J. Soc. Mot. Pict. Telev. Engrs*, Sept. 1956, Vol. 65, No. 9, pp. 488–492.) Design details and operating characteristics are given of newly developed studio equipment, which includes distribution and correcting amplifiers, a relay switching unit and regulated power supplies.

621.397.62 : 535.623 : 621.385.832 **1929**

A New Flat Picture Tube.—D. Gabor. (*J. Telev. Soc.*, Oct./Dec. 1956, Vol. 8, No. 4, pp. 142–145.) See 588 of February.

621.397.62 : 621.317.7 : 621.374.3 **1930**

A Spot and Graticule [pattern] **Generator for Laboratory Use.**—Hücking. (See 1856.)

621.397.62 : 621.373.43 **1931**

Television Sweep Generation with Resonant Networks and Lines.—T. C. G. Wagner: W. D. White: K. Schlesinger. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, pp. 362–364.) Discussion on 2893 of 1956 (Schlesinger) and author's reply.

VALVES AND THERMIONICS

621.314.63 : [546.28 + 546.289 **1932**

Excess Surface Currents on Germanium and Silicon Diodes.—W. T. Eriksen, H. Statz & G. A. de Mars. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 133–139.) Excess current is associated with an anomalous surface inductance as a function of bias voltage. Conduction in outer surface states can explain observed data.

621.314.63 : 546.289 **1933**

Slow Relaxation Phenomena in Junction Diodes.—T. B. Watkins. (*Proc. phys. Soc.*, 1st Dec. 1956, Vol. 69, No. 444B, pp. 1353–1355.) The relaxation effect is demonstrated by measurements of the reverse current in a Ge junction diode, for various ambient atmospheres.

621.314.63 : 546.289 **1934**

Measurements of H.F.-Diode Impedance as a Function of Bias Voltage.—H. Flietner & G. Hesse. (*Hochfrequenztech. u. Elektroakust.*, Sept. 1956, Vol. 65, No. 2, pp. 41–46.) Description of a method for determining the impedance bias characteristic of Ge point-contact rectifiers. The effect of bias voltage on the real part of the barrier-layer impedance is discussed with reference to the rectifier equivalent circuit.

621.314.632 : 537.311.33 **1935**

Frequency Characteristics of Germanium Junction Diodes at a Small Alternating Voltage.—S. G. Kalashnikov, N. A. Penin & K. V. Yakunina. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1058–1070.) An experimental investigation of Ge-In alloy diodes is reported. Results, which are presented graphically, are in agreement with calculated characteristics based on theoretical work by Kalashnikov & Penin (1889 of 1956). The measurements reported were carried out at frequencies between 1 kc/s and 100 Mc/s.

621.314.632 : 537.311.33 **1936**

Properties of Germanium Detectors with Welded Junction at Ultra-high Frequencies.—N. A. Penin & N. E. Skvortsova. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1071–1079.) The capacitance and impedance of the barrier layer was experimentally determined in the frequency range 1–6 kMc/s for several values of positive bias current. The capacitance was inversely proportional to the square root of frequency and both the capacitance and resistance varied linearly with the bias current. The results are in agreement with the diffusion theory of electron-hole junctions taking into account the effect of injection of non-equilibrium charge carriers.

621.314.632 : 537.311.33 **1937**

Investigation of Breakdown of Germanium Junction Diodes.—B. M. Vul & A. P. Shotov. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1080–1085.) Application of voltage pulses leads to breakdown due to shock ionization; breakdown by constant voltages depended on the structure of the *p-n* junction and on heat-transfer conditions.

621.314.632 : 537.311.33 **1938**

Investigation of Rectification Properties of Point-Contact Germanium Diodes.—K. B. Tolpygo & V. A. Fomenko. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1093–1105.) Report on theoretical and experimental investigations. The experimental results indicate that at small voltages point-contact diodes made of low-resistivity (2–4-Ω.cm) Ge with weak forming (forming current $=0\cdot2$ A) possess a superior forward characteristic and higher detection efficiency than those using 20–25-Ω.cm Ge and strong forming.

621.314.632 : 537.311.33 **1939**

Electrochemical Method for Improving the Quality of the Electron-Hole Transition Region in a Selenium Rectifying Element.—L. Yu. Belenkova, I. Kh. Geller, D. N. Nasledov & F. M. Tartakovskaya. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1121–1126.)

621.314.7 **1940**

Bibliography of Literature on Semiconductor Triodes (1948–1956).—V. V. Pavlov. (*Avtomatika i Telemekhanika*, Oct. 1956, Vol. 17, No. 10, pp. 946–952.) About 150 references including some to Russian literature.

621.314.7 **1941**

Parameters and Construction of Semiconductor Amplifying Devices of Home [U.S.S.R.] **Manufacture.**—A. V. Krasilov. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1113–1120.) Tables of characteristics and section drawings of Russian transistors.

621.314.7 **1942**

Transistor Graphical Symbols.—(*Wireless World*, April 1957, Vol. 63, No. 4, pp. 194–198.) A critical analysis of existing ideas and conventions.

621.314.7 **1943**

Some Aspects of Transistor Progress.—H. W. Loeb. (*J. Brit. Instn Radio Engrs*, Feb. 1957, Vol. 17, No. 2, pp. 125–128.) Discussion of 295 of January and author's reply, stressing that developments have reached a stage where, for a considerable number of important fields of application, several types of structure have been proved feasible. Temperature limitations in power transistors were due to mechanical changes or alteration of parameters, and satisfactory operation of Ge alloyed-junction types was possible over temperatures ranging from −55°C to +85°C. Reliability was very high, even for point-contact types. The outputs of junction photocells were at present an order of magnitude higher than those of vacuum photocells.

621.314.7 **1944**

Transistor Impedance Matching.—H. P. Williams. (*Electronic Radio Engr*, April 1957, Vol. 34, No. 4, pp. 128–129.) Simplified matching formulae applicable to junction transistors are presented and attention is drawn to the property that the product of the input and output impedances is, for practical purposes, the same for all three configurations.

621.314.7 **1945**

The Dependence of Junction-Transistor Current Amplification on the Emitter Current.—E. R. Hauri. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, 1st Nov. 1956, Vol. 34, No. 11, pp. 441–451.) A theoretical investigation of the α characteristics at high frequencies and large emitter currents is reported. Results indicate that the formulae derived by Webster (2798 of 1954) need to be modified. Calculated characteristics of commercial transistors are in good agreement with experimental results.

621.314.7 **1946**

Measurements on Alloy-Type Transistors with Varying Collector Voltage.—D. M. Evans. (*Brit. J. appl. Phys.*, Jan. 1957, Vol. 8, No. 1, pp. 44–45.) Dependence of the effective base width and α cut-off frequency on collector voltage.

621.314.7 **1947**

The Spacistor, a New Class of High-Frequency Semiconductor Devices.—H. Statz & R. A. Pucel. (*Proc. Inst. Radio Engrs*, March 1957, Vol. 45, No. 3, pp. 317–324.) New devices are considered in which electrons or holes are injected directly into space-charge regions of reverse-biased junctions, avoiding the diffusion of carriers through field-free regions. In the 'spacistor' the junction is biased at a voltage such that the injected carriers are multiplied by the avalanche process. Difficulties with the accumulation of generated carriers in front of the emitting contact are discussed, and applications are considered.

621.383 : 546.289 **1948**

Efficiency and Characteristics of a Germanium Photocell with an Electron-Hole Junction.—V. S. Vavilov & L. S. Smirnov. (*Radiotekhnika i Elektronika*, Aug. 1956, Vol. 1, No. 8, pp. 1147–1154.)

621.383.27 **1949**

On the Reduction of the Dark Current of Photomultipliers.—Zs. Náray. (*J. sci. Instrum.*, Dec. 1956, Vol. 33, No. 12, pp. 476–478.) Two methods are suggested: (*a*) effectively reducing the sensitive area of the photocathode by defocusing the electrons from the unilluminated portion; (*b*) the application of a suitable shield potential to a conducting layer on the outer surface of the photomultiplier envelope. The reduction obtained is equivalent to cooling by about 100°C.

621.383.4 : 535.37 : 621.318.57 **1950**

Principles of the Light-Amplifier and Allied Devices.—T. B. Tomlinson. (*J. Brit. Instn Radio Engrs*, March 1957, Vol. 17, No. 3, pp. 141–154.) The topics surveyed and discussed are light-amplifier systems, electroluminescent panels, photoconductive materials, and electro-optical switching devices.

621.385 : 621.395.64 **1951**

Electron Tubes for the Transatlantic Cable System.—J. O. McNally, G. H. Metson, E. A. Veazie & M. F. Holmes. (*Bell Syst. tech. J.*, Jan. 1957, Vol. 36, No. 1, pp. 163–188.) The design considerations governing the development of the valve Type 6P12 by the General Post Office and the valve Type 175HQ by the Bell Telephone Laboratories are discussed together with problems arising in manufacture and selection. Electrical characteristics and life-test data are given.

621.385 : 621.396.822 **1952**

Noise and its 'Spectrum'.—F. N. H. Robinson. (*J. Brit. Instn Radio Engrs*, Feb. 1957, Vol. 17, No. 2, pp. 115–119.) The physical ideas underlying the familiar equation for shot noise in a temperature-limited current are explained. The mathematical analysis is based on Campbell's theorem, which is proved, and some consideration is given to the meaning of the averages which appear in expressions describing noise.

621.385.029.6 **1953**

Electron Tubes for Microwave Applications—a Survey of Available Types.—P. K. Worsley. (*Brit. Commun. Electronics*, Nov. & Dec. 1956, Vol. 3, Nos. 11& 12, pp. 606–609 & 668–669.) A tabulation of the principal characteristics of British commercial types.

621.385.029.6 **1954**

Stability of Periodic-Field Beam Focusing.—K. K. N. Chang. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1527–1532.) An analytical solution for beam focusing with a sinusoidal field is found and from it a stability criterion is derived.

621.385.029.6 **1955**

Formation of High-Density Electron Beams.—G. R. Brewer. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 7–15.) Physical principles underlying the design and characteristics of electron guns for high-perveance beams are considered, with a description of experimental techniques and results of studies of gun and beam performance.

621.385.029.6 **1956**

On the Effect of the Transition Region upon an Electron Beam Constrained by Brillouin Flow.—B. W. Manley. (*J. Electronics*, Nov. 1956, Vol. 2, No. 3, pp. 241–246.) Analysis indicates that Müller's result (2827 of 1953) is not valid. The position of the beam throat will depend on the extent of the transition region and the strength of the magnetic field. Design data are given for a range of beam parameters.

621.385.029.6 **1957**

Synchronization of a Reflex Klystron.—I. I. Minakova & N. V. Stepanova. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 805–808.) Synchronization by a small sinusoidal e.m.f. of frequency near the natural resonance of the klystron is discussed.

621.385.029.6 **1958**

One Mode of Self-Oscillation of the Space Charge in a Nonslotted Magnetron.—M. I. Kuznetsov. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 785–793.)

621.385.029.6 **1959**

Contribution to the Large-Signal Theory of Travelling-Wave Valves.—G. Mourier. (*Ann. Radioélect.*, Oct. 1956, Vol. 11, No. 46, pp. 271–280.) The saturation condition arising in O-type travelling-wave valves when electron and wave velocities are equal is investigated. See also 2571 of 1956 (Tien).

621.385.029.6 **1960**

Plasma Wavelength and Low-Noise Travelling-Wave Valve.—J. Labus & R. Liebscher. (*Arch. elekt. Übertragung*, Oct. 1956, Vol. 10, No. 10, pp. 421–423.) The calculation of the plasma wavelength in an electron beam is usually based on the assumption that the electrons do not rotate round the axis. With a finite space charge, this condition can occur only if the magnetic focusing field is infinite. The dependence of the reduction factor on the distribution of magnetic flux along the beam is determined, and the theory is applied to the design of the drift region to give low noise in a travelling-wave valve.

621.385.029.6 **1961**

Conditions for the Minimum Noise Figure of Travelling-Wave Valves.—J. Labus, R. Liebscher & K. Pöschl. (*Arch. elekt. Übertragung*, Nov. 1956, Vol. 10, No. 11, pp. 486–490.) The length of the drift space and the potential distribution between cathode and drift space are considered.

621.385.029.6 **1962**

Experimental Investigation of a Backward-Wave Valve with Bifilar Helix.—V. P. Kiryushin. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 798–804.) The valve investigated oscillated in the continuous waveband 4·08–39·5 cm at voltages from 3 400 to 20 V, with a power output of 80 mW, at an efficiency of up to 2%.

621.385.029.6 : 537.533 **1963**

Excitation of Space-Charge Waves in Drift Tubes.—A. H. Beck. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 140–141.) Comment on 2912 of 1956 (Scotto & Parzen).

621.385.029.6 : 621.3.083 **1964**

A Sensitive Method of Measuring the Reflections and Stability in High-Gain Travelling-Wave Valves.—W. Klein. (*Arch. elekt. Übertragung*, Nov. 1956, Vol. 10, No. 11, pp. 477–482.) The method described permits the separation of internal and external reflections and the location of the disturbances. It can be used to check valve stability and the quality of the complete amplifier.

621.385.029.6 : 621.372.2 **1965**

Measurement of the Coupling Impedances of Delay Lines [in travelling-wave valves].—R. Müller. (*Arch. elekt. Übertragung*, Oct. 1956, Vol. 10, No. 10, pp. 424–428.) Two previously described experimental methods [2061 of 1950 (Lapostolle) and 3155 of 1955 (Aikin)] are compared, with particular reference to the investigation of lines with band-pass characteristics.

621.385.029.6 + 621.372.56.029.6] : 621.396.41 **1966**

Ultra-high-Frequency Valves for a Wide-Band Radio-Link System.—W. Kleen. (*Arch. elekt. Übertragung*, Oct. 1956, Vol. 10, No. 10, pp. 415–420.) A f.m. radio-link system inaugurated in Denmark in the summer of 1956 is discussed. Operation is in the frequency band 3·8–4·2 kMc/s, the channel width being 30 Mc/s, and accommodating 600 speech channels or one television channel. A Type-RW3 travelling-wave valve with saturation power of 9 W is used as transmitting valve; it has permanent-magnet focusing designed to reduce stray magnetic fields. A Type-RK25 reflex klystron with L cathode is used as modulator. The output of the travelling-wave valve is isolated from the aerial line by means of a unidirectional attenuator comprising a helix embedded in a ferrite cylinder.

621.385.029.6 : 621.396.822 **1967**

The Transformation of [noise] **Power Spectra in Electron Beams.**—H. Pötzl. (*Arch. elekt. Übertragung*, Sept. 1956, Vol. 10, No. 9, pp. 376–382.) From the transformation equations given by Haus (3123 of 1955) a simple expression is derived for the determination of coherence conditions between current and potential fluctuations. The influence of coherence and the effect of lossy networks on the minimum noise figure of amplifiers are investigated. The analysis of a loss-free six-terminal network leads to a generalization of the results obtained by König (1277 of April).

621.385.029.63 **1968**

Micro-miniature [triode] **Tube for U.H.F. and High Temperature.**—(*Elect. Mfg*, Nov. 1955, Vol. 56, No. 5, pp. 154–155.) The valve Type 6BY4 described has a ceramic envelope and electrodes consisting mainly of titanium. Its dimensions are $\frac{5}{16}$ in. diameter by $\frac{3}{8}$ in. long; it operates at frequencies up to 900 Mc/s and can withstand a temperature of 500°C.

621.385.029.64 **1969**

A Twin-Helix Travelling-Wave Power Valve with 50-dB Gain at 4 kMc/s.—W. Klein & W. Friz. (*Nachrichtentech. Z.*, Oct. 1956, Vol. 9, No. 10, pp. 476–482.) The valve Type LW53-V described is intended for high-gain applications over the range 3·6–4·2 kMc/s. Design problems arising from high-gain requirements are discussed.

621.385.029.64 **1970**

A Low-Noise Travelling-Wave-Tube Amplifier for the 4 000-Mc/s Communications Band.—D. H. O. Allen & J. M. Winwood. (*J. Brit. Instn Radio Engrs*, Jan. 1957, Vol. 17, No. 1, pp. 75–85.) "The factors which influence the performance of a low-noise travelling-wave tube are discussed and design data are developed for a particular tube. The mechanical design is considered and some performance curves presented."

621.385.029.64 **1971**

A Medium-Power Travelling-Wave Tube for 6 000-Mc/s Radio Relay.—J. P. Laico, H. L. McDowell & C. R. Moster. (*Bell Syst. tech. J.*, Nov. 1956, Vol. 35, No. 6, pp. 1285–1346.) Discussion of a travelling-wave amplifier which gives 30-dB gain at 5-W output in the 5 925–6 425-Mc/s common-carrier band. A description of the tube and detailed performance data are given.

621.385.032.21 **1972**

Mixed Monolayers of Barium and Calcium on Tungsten.—I. Brodie & R. O. Jenkins. (*Proc. phys. Soc.*, 1st Dec. 1956, Vol. 69, No. 444B, pp. 1343–1344.) The saturated thermionic emission from tungsten wire at a constant temperature was measured as a function of the time for which the wire was exposed to the mixed vapour. Maximum emission was found for a monolayer with 25% calcium.

621.385.032.21 : 621.396.822 **1973**

An Anomalous Periodic Flicker Effect.—O. M. White & K. G. Emeleus. (*J. Electronics*, Jan. 1957, Vol. 2, No. 4, pp. 358–367.) Low-frequency oscillations are observed in cylindrical-anode diodes when high cathode heating currents are used. A model of an oscillating space charge with stationary transverse wave patterns is discussed.

621.385.032.216 **1974**

The Nature of the Emitting Surface of Barium Dispenser Cathodes.—I. Brodie & R. O. Jenkins. (*Brit. J. appl. Phys.*, Jan. 1957, Vol. 8, No. 1, pp. 27–29.) It is deduced from data examined that the tungsten surface of an L-type cathode must be covered with a layer of oxygen on which the barium is adsorbed. Emission from cathodes impregnated with barium aluminate results mainly from a similar layer on the tungsten, but with barium-calcium-aluminate the enhanced emission is mostly derived from the impregnant itself, the emitting surface being probably a thin layer of calcium oxide activated by barium.

621.385.032.216 **1975**

An Engineering Study of Oxide-Coated Cathode.—K. Amakasu. (*Rep. elect. Commun. Lab., Japan*, Sept. 1956, Vol. 4, No. 9, pp. 8–27.) Results of investigations of initial decay and noise are summarized for various types of cathodes. The relation between crystal shape and emission and the effects of impurities, electron bombardment, gas, etc., are shown in tables and graphs. and methods of improvement are suggested,

621.385.032.216 **1976**

On the Initial Decay of Thermionic Emission from Oxide-Coated Cathodes.—K. Ishikawa. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser.A*, Oct. 1956, Vol. 8, No. 5, pp. 421–440.) Report of detailed investigations originally outlined in 868 of 1952 (Hibi & Ishikawa).

621.385.032.216 **1977**

Influence of the Cathode Base on the Chemical Activation of Oxide Cathodes.—R. W. Peterson, D. E. Anderson & W. G. Shepherd. (*J. appl. Phys.*, Jan. 1957, Vol. 28, No. 1, pp. 22–33.) Radioactive tracer techniques show that strontium evaporation from an oxide-coated cathode indicates the rate of reduction of the coating by reducing agents in the base metal. The cathode activity without current drain correlates experimentally and qualitatively on a theoretical basis, with rates of coating reduction.

621.385.032.216 **1978**

Donor Concentration Changes in Oxide-Coated Cathodes Resulting from Changes in Electric Field.—H. J. Krusemeyer & M. V. Pursley. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1537–1545.) Sudden changes in d.c. drawn from, or to, the coating produce large changes in work function characterized by two, sometimes three, time constants.

621.385.032.216 : 546.841.4-31 **1979**

Some Physical Properties of High-Density Thorium Dioxide.—S. M. Lang & F. P. Knudsen. (*J. Amer. ceram. Soc.*, Dec. 1956, Vol. 39, No. 12, pp. 415–424.) Data are tabulated of the mechanical properties of specimens of ThO_2 and ThO_2 + CaO solid solutions of 99% of theoretical density.

621.385.032.216.1 : 546.841.4-31 **1980**

The Thermionic Emission of Thoria Cathodes under Pulse Conditions.—G. Déjardin, G. Mesnard & R. Uzan. (*Cah. Phys.*, Oct. 1956, Vol. 10, No. 74, pp. 1–21.) Report of measurements on thoriated tungsten cathodes subjected to millisecond voltage pulses to reach temperatures in the range 1 400–1 900° K. The amplitude and speed of decay of the emission were investigated as a function of temperature and activation and the results were used to derive the equation of the decay curve. For tests under static conditions, see 2840 of 1953 (Mesnard).

621.385.1 **1981**

A New Method of Investigating the Microphony of Valves: Part 1.—L. P. Valkó. (*Hochfrequenztech. u. Elektroakust.*, Sept. 1956, Vol. 65, No. 2, pp. 59–65.) In the equipment described valves are vibrated by an electrodynamic transducer which is controlled by a white-noise generator. The advantages and limitations of the method are discussed; repeated tests gave consistent results.

621.385.14-713 **1982**

'Duct Cooling' (Kanalkühlung), a Method of Evaporation Cooling for High-Power High-Frequency Oscillator and Transmitter Valves.—C. Protze. (*Telefunken Ztg*, June 1956, Vol. 29, No. 112, pp. 87–92. English summary, pp. 132–133.) In the valves Type RS822 and Type RS826 heat from thick-walled cylindrical anodes is efficiently extracted by water evaporation. The walls are perforated by small-diameter ducts parallel to the cylinder axis, and, with the anode partly submerged in a water container, the upward surge of steam bubbles in the ducts ensures rapid circulation without pumps. Advantages include freedom from vibration, great overload capacity and the possibility of downward steam extraction convenient in s.w. transmitters. A dissipation of over 450 W/cm² can be obtained from the energized anode surface.

621.385.2 : 621.362 **1983**

Thermionic Diodes as Energy Converters.—H. Moss. (*J. Electronics*, Jan. 1957, Vol. 2, No. 4, pp. 305–322.) An analysis of the conversion phenomena in a plan or system relating power output to various diode parameters. The exact diode characteristic solution is compared with the Langmuir approximate expansion formula.

621.385.2/.3].029.63 **1984**

Investigation of Electronic Conductances of Planar Valves.—A. I. Kostienko. (*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 809–813.) Resuts are presented of measurements of the input admittances of diodes and lighthouse triodes in the 10-cm-λ band. The results are compared with theory.

621.385.3 **1985**

Triode Amplification Factor.—P. Hammond. (*Electronic Radio Engr*, April 1957, Vol. 34, No. 4, pp. 135–137.) Re-examination of current theory with reference to Moullin's analysis (*Proc. Instn elect. Engrs*, Part C, March 1957, Vol. 104, No. 5, pp. 222–232).

621.385.4 032.25 : 537.533 **1986**

The Suppression of Screen-Grid Emission by Carbon.—J. A. Champion. (*Brit. J. appl. Phys.*, Nov. 1956, Vol. 7, No. 11, pp. 395–399.) The emission from an unsuppressed screen grid is shown to be of the same magnitude as that from a thin activated layer of barium oxide. The effect of carbon coating is to increase with time the emission at temperatures below 900°C; at temperatures above 950°C the emission decays to a negligibly small value in a few minutes. The mechanism of the suppression is the chemical reduction of the deposited barium oxide to barium which evaporates.

621.385.83 **1987**

Focusing Low-Energy Electron Beams.—W. W. H. Clarke & L. Jacob. (*J. appl. Phys.*, Dec. 1956, Vol. 27, No. 12, pp. 1519–1524.) The distributions of the electrons in beams of energies 30–70 V were studied using a system of concentric collectors in a c.r. tube.

621.385.832 **1988**

The Picture Quality of a Modern Oscillograph Tube.—(*Telefunken Ztg*, June 1956, Vol. 29, No. 112, pp. 124–126. English summary, p. 135.) A raster photograph illustrates the high degree of resolution and linearity of the electrostatically focused c.r. tube Type DG13-54. The raster 87 mm high consists of 260 lines 55 mm long and about 0·2 mm thick.

621.385.832 **1989**

Method of Measuring Spot Size of Cathode-Ray Tube.—R. B. Kuhn & D. Levine. (*Commun. & Electronics*, July 1956, No. 25, pp. 357–359. Discussion, p. 359.) An objective method is described in which a slit mask and photocell are used. Gaussian distribution of light flux density is assumed.

621.385.832 : 535.371.07 **1990**

Cathode-Ray-Tube-Screen Charging and Conditions Leading to Positive-Ion Deterioration.—A. B. Laponsky, M. J. Ozeroff, W. A. Thornton & J. R. Young. (*J. electrochem. Soc.*, Sept. 1956, Vol. 103, No. 9, pp. 498–507.) The relation of screen charging effects to gas pressure and screen surface conditions and dimensions is discussed on the basis of existing literature, some previously unpublished, and experiments. The influence of tube and raster geometry on observed deterioration patterns is examined and results are summarized regarding the effects of anode coating material and screen potentials leading to burn patterns in the form of a cross.

621.385.832 : 621.397.62 : 535.623 **1991**

A New Flat Picture Tube.—D. Gabor. (*J. Telev. Soc.*, Oct./Dec. 1956, Vol. 8, No. 4, pp. 142–145.) See 588 of 1957.

621.385.832.032 **1992**

The Technology of Electrostatic-Storage Cathode-Ray Tubes.—P. Choffart. (*Onde élect.*, Oct. 1956, Vol. 36, No. 355, pp. 815–821.) An outline of some of the manufacturing problems.

MISCELLANEOUS

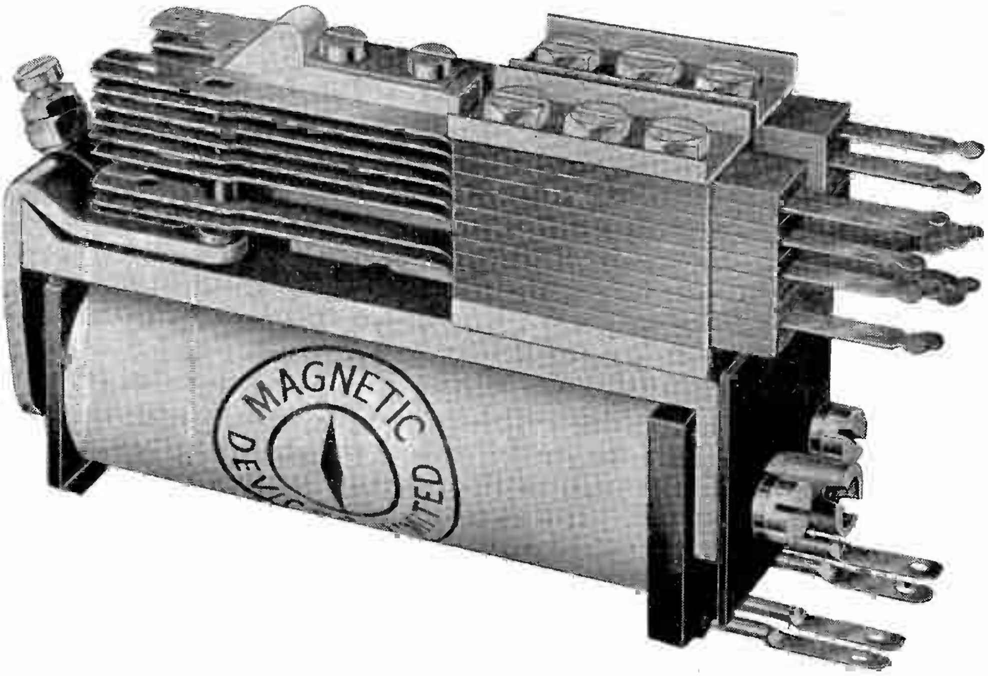
621-52 **1993**

Man as a Link in Complex Machine Systems.—G. H. Mowbray. (*Sci. Mon.*, Dec. 1956, Vol. 83, No. 6, pp. 269–276.) The performance, particularly the speed of response, of man as a series or parallel link in a control system is discussed. Instrument dials, providing the input to the link, and control devices receiving its output should be designed to facilitate rapid reading and operation respectively.

621.396 : 061.3 **1994**

Documents and Papers Read at the Scientific Conference of the [U.S.S.R.] Ministry of Higher Education on Radioelectronics (Gorki, January 1956).—(*Radiotekhnika i Elektronika*, June 1956, Vol. 1, No. 6, pp. 878–887.) Abstracts and references to 66 papers presented at the conference. The principal topics were (*a*) radio astronomy, (*b*) propagation of radio waves, and (*c*) physics of ultra high frequencies.

series 305 relay



P.O. 3000 RELAY

This Relay is the well known P.O. 3000 Relay and can be supplied with coils wound for standard voltages up to 250 volts D.C.

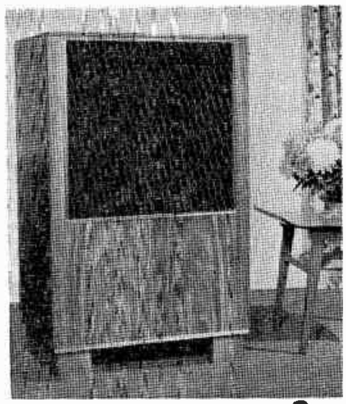
Contact assemblies are available up to six pole changeover and alternative rivets can be supplied to suit varying duties. The Series 305 Relay can be slugged for make or break action and coils can be vacuum impregnated for tropical and humid conditions.

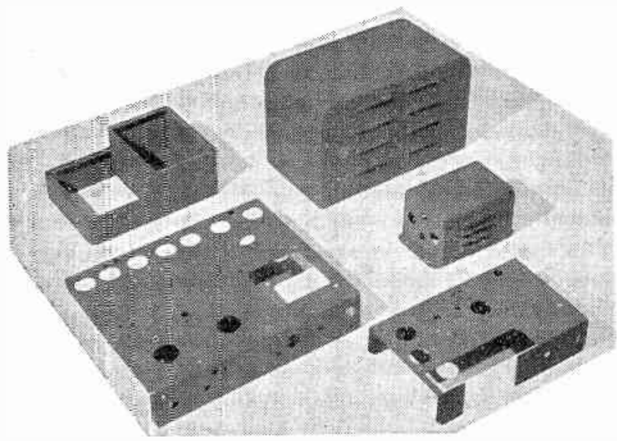
Magnetic Devices LTD

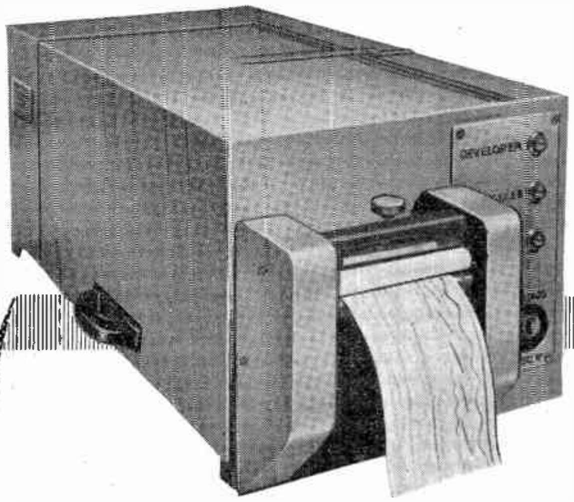
A.I.D. & A.R.B. approved

EXNING ROAD · NEWMARKET · SUFFOLK

Telephone: Newmarket 3181/2/3 Telegrams: MAGNETIC, Newmarket.







* southern oscillogram processor

This machine automatically processes under full daylight conditions any length of paper record from a few inches to hundreds of feet in widths up to 6″.

Please write for further details and a copy of our Oscillogram Processor Brochure

SOUTHERN INSTRUMENTS OSCILLOGRAPH DIVISION

Proprietor: SOUTHERN INSTRUMENTS LTD.

CAMBERLEY SURREY

Telephone No. Camberley 2230 (3 lines) Telegraphic address Minrak, Camberley England

---

The STANDARD TELECOMMUNICATION LABORATORIES LIMITED

announce the expansion of its research and development programme which necessitates an increase in its Research Staff.

Applications are therefore invited from suitably qualified and/or experienced personnel in the following fields:

Data processing systems: digital circuit techniques: micro-wave communication system, antennae, and millimetre waves: transistor development and applications: circuit development for telecommunications and television: The overall performance of communication systems of all types.

Some positions will offer opportunities for foreign travel.

Applications for the above posts should be addressed to:

MR. P. J. ROGERS, PERSONNEL MANAGER
STANDARD TELECOMMUNICATION LABORATORIES LIMITED
Progress Way, Great Cambridge Road, Enfield, Middlesex

VICKERS-ARMSTRONGS (AIRCRAFT) LTD

have several vacancies for

ELECTRONICS ENGINEERS

Interesting work in newly formed section engaged on the application of electronics to the numerical control of machine tools and allied projects. Applicants should preferably be between the ages of 26 and 40 years. Experience in this type of electrical engineering essential, and a Degree a desirable asset. The positions offer excellent prospects and scope.

Houses can be made available to suitable applicants.

Write giving full particulars, quoting reference No. 3387, to:

Personnel Officer
South Marston Works, nr. Swindon, Wilts

NEW ZEALAND

Radio Mechanicians

Applications for posts with the New Zealand Post and Telegraph Department are invited from fully experienced single men between 21 and 30. Excellent pay and conditions. Free passages are granted to successful applicants. For full information apply to New Zealand Migration Office, Adelphi Building, John Adam Street, London, W.C.2, quoting this advertisement.

ELECTRONIC & RADIO ENGINEER

CLASSIFIED ADVERTISEMENTS

Advertisement Rates. *6d. per word, minimum charge 6/-, each paragraph charged separately. Remittances payable to Iliffe & Sons Ltd., Dorset House, Stamford St., S.E.1. Series discount of 15% is allowed for 12 consecutive insertions.*

Box Numbers *are available at an additional charge of 2/- to defray cost of registration and postage. Replies should be addressed Box No. 0000, c/o "Electronic & Radio Engineer", Dorset House, Stamford Street, London, S.E.1.*

Semi-Display *advertisements with centralized lines £1/15/- per single column inch—no additional charge for Box Numbers. The Publishers are not responsible for clerical or printers' errors although every care is taken to avoid mistakes.*

Press date for the July 1957 issue is first post Tuesday, 25th June 1957

SITUATIONS VACANT

Applications are invited for pensionable posts
as
EXAMINERS
in the
PATENT OFFICE

TO undertake the official scientific, technical and legal work in connexion with Patent applications.

AGE at least 21 and under 35 years on 1st January, 1957, with extension for regular Forces' service.

CANDIDATES must have (or obtain in 1957) 1st or 2nd class honours in Physics, Organic or Inorganic Chemistry, Mechanical or Electrical Engineering or in Mathematics, or an equivalent qualification, or have achieved a professional qualification, e.g. A.M.I.C.E., A.M.I.Mech.E., A.M.I.E.E., A.R.I.C. For a limited number of vacancies candidates with 1st or 2nd class honours degrees in other subjects—scientific or otherwise—will be considered. Exceptional candidates otherwise qualified by high professional attainments will be considered.

STARTING pay for five-day week of forty-two hours in London between £605 and £1,120 (men) according to post-graduate (or equivalent) experience and National Service. Maximum of scale £1,345. Women's pay above £605 slightly lower but is being raised to reach equality with men's in 1961. Good prospects of promotion to Senior Examiner rising to £2,000 (under review) and reasonable expectation of further promotion to Principal Examiner.

APPLICATION form and further particulars from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting S128/57 and stating date of birth.

INTERVIEW Boards will sit at intervals, as required. Early application is advised. [1058

THE ROYAL COLLEGE
OF
SCIENCE AND TECHNOLOGY
GLASGOW
(Affiliated to the University of Glasgow)
Department of Electrical Engineering

APPLICATIONS are invited for the following Lectureships from candidates holding a good degree in Electrical Engineering, and with subsequent experience in the special fields indicated. The work will be on the undergraduate and postgraduate levels, with excellent facilities for the supervision and conduct of research programmes.

1. Lecturer in Electronics (Microwaves).
2. Lecturer with a special interest in High Voltage Engineering or Electrical Measurements.

SALARY scale in the range £900 × £50 to £1,350 × £75 to £1,650 p.a., with F.S.S.U. and family allowances. There is an efficiency bar at £1,350. Forms of application are available from the Secretary of the College. [1073

SALES Engineer required to join Scottish Representatives of Firm manufacturing High Frequency Induction Heating, Dielectric Heating and Plastic Welding equipment. Basic knowledge of electronics plus general electrical knowledge required but technical experience in Induction and Dielectric application work essential. Apply in writing giving details of previous experience and salary required to Morris, Warden & Co., Ltd., 10 Royal Crescent, Glasgow, C.3. [1072

ROYAL DEVON AND EXETER HOSPITAL, Exeter, invite applications for the post of Recordist Grade 1 in technical charge of the Electrocardiography and Electroencephalography Department. Salary scale £540 × £20 (4) × £25 (2)—£670 per annum. Candidates should have a sound basic knowledge of electrical and electronic equipment, preferably with five years' experience of similar work in hospitals or industry. Applications, stating age, education, qualifications and experience, together with two testimonials or the names of two referees, to the Hospital Secretary. [1076

SITUATIONS VACANT

PETO SCOTT
ELECTRICAL INSTRUMENTS LIMITED
Addlestone Road, Weybridge

THERE are vacancies for several experienced engineers with suitable qualifications for the design of domestic television receiving equipment, or transmission equipment, as appropriate to their experience.

GOOD salaries are offered and employment would be at our Weybridge factory, where there are excellent working conditions and all normal facilities. There is an adequate train and Green Line service and many local housing projects for those who are interested in living in the neighbourhood.

APPLY: Chief Engineer. [1067

REILLY HYDRAULICS LIMITED
AUTOMATION:
An Electronic Engineer or Physicist

IS required to work on a small group of problems in the field of Electronic Machine Tool Control, Automatic Process Controls, Laboratory and Industrial Measuring Instruments, Hospital Physics.

A formal training in science with a degree or equivalent and some experience of design work is preferable. A laboratory is situated near Woking, where original development work and small-scale production are in progress.

THIS is an opportunity for a genial character to work in an expanding group where the rewards are commensurate with the effort.

APPLY in writing to: Reilly Hydraulics, Ltd., Albert Drive, Sheerwater, Woking. [1077

BRITISH THOMSON-HOUSTON CO., LTD.

VACANCIES exist in the company's Research Laboratory at Rugby for electrical engineers with Higher National Certificate or equivalent qualification, to work under experienced group leaders on the development of new semiconductor devices.

APPLICANTS, who should be free from National Service obligations, are invited to write to the Director of Research, The British Thomson-Houston Co., Ltd., Rugby, stating age, qualifications and experience, and quote reference HGR. [1068

COVENTRY TECHNICAL COLLEGE

APPLICATIONS invited for appointment as Lecturer in Electronic Engineering—mainly for full-time and part-time courses in Electronic Engineering and Telecommunications. Candidates should be honours graduates or equivalent and preferably have had some industrial or teaching experience. Commencing date September, 1957, or by arrangement. Salary, Burnham Technical Scale, £1,200 × 30—£1,350. Application forms and further particulars from Director of Education, New Council Offices, Coventry. [1069

TECHNICIANS (Aeradio) Grade I required by East Africa High Commission Directorate of Civil Aviation on probation for pensionable employment. Salary scale (including inducement pay) £813 rising to £1,173 a year. Commencing salary according to experience. Outfit allowance £30. Free passages. Liberal leave on full salary after each tour 30/36 months. Candidates not over 38 years of age, should preferably possess C. and G. Certificate in Telecommunications Principles or Radio Part III or equivalent. They must have had at least three years' experience in erection and maintenance of ground station transmitters, radio and radar navigational aids and aerial systems and should have up-to-date knowledge of workshop practice. Knowledge of teleprinter and perforator equipment servicing or diesel electric power plant maintenance an advantage. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience, and quote M2C/42260/WJ. [1066

SITUATIONS VACANT

ELECTRO-ENCEPHALOGRAPHY Recordist required for new department at Cherry Knowle Hospital, Ryhope, Nr. Sunderland. Trainee with minimum qualifications of City and Guilds Certificate in Electrical or Radio Engineering, or equivalent, would be considered.

ALTERNATIVELY, applications may be considered from young ladies to train as Recordist. Good educational standard essential, preferably Higher School Certificate.

ANY necessary training would be arranged in either case. Health Service national salary scales and conditions of service. Written applications to the Group Secretary, above address. [1074

ELECTRICAL Branch Instructor required by Government of Hong Kong for Royal Naval Volunteer Reserve. Appointment on contract for one tour of three years in first instance. Salary in scale (including expatriation pay and present temporary allowance): (*i*) single man: £1,020 rising to £1,227 a year; (*ii*) married man without children: £1,135 rising to £1,362 a year; (*iii*) family man: £1,250 rising to £1,496 a year. Gratuity £150 a year. Free passages. Liberal leave on full salary. Candidates, under 45, must have served in the Royal Navy as Chief Radio Electrical Artificers. Write to the Crown Agents, 4 Millbank, London, S.W.1. State age, name in block letters, full qualifications and experience and quote M2C/42286/WJ. [1070

ELECTRONICS. One or two vacancies exist for research workers with a leaning towards electronics who have taken a degree in Electrical Engineering or Physics and consideration would also be given to those holding H.N.C. qualifications. Work is of a diverse nature but currently includes applications of transistors and other semi-conductors, d.c. amplifiers, electrical type flowmeters and transducing elements. Applications will be welcome from those with some experience or those about to graduate and the salaries offered will be within the range £600–£850. Pleasant working conditions in semi-rural surroundings but easy access to London. Applications should be sent in writing to British Scientific Instrument Research Association, Sira, South Hill, Chislehurst, Kent. [1075

PLESSEY NUCLEONICS, LTD., have vacancies for Electronic Engineers to work on the design of reactor instruments, pulse circuits, and other applications of electronics to nuclear problems. Both Senior and Junior posts are offered. All applicants should possess a thorough knowledge of basic electronic theory, a degree in science or electrical engineering, H.N.C., or appropriate equivalent standards of technical education for the two grades. Previous experience in nucleonics advantageous but not essential. The other important qualifications are enthusiasm and initiative to progress in this new and expanding field. These posts will carry attractive salaries commensurate with qualifications and experience. Apply in writing to Chief Engineer, Plessey Nucleonics, Ltd., Weedon Road, Northampton. [1052

D.S.I.R. require Experimental Officers and Assistant Experimental Officers at Radio Research Station, Datchet, Berks, to (*i*) assist in radio research and (*ii*) prepare abstracts of scientific and technical articles on radio research and development. Qualifications in Physics or Electrical Engineering, minimum G.C.E. (Advanced level) in two scientific subjects or equivalent. Over 22 pass degree, H.N.C. or equivalent generally expected. Experience in radio research or development, or communications an advantage. For posts (*ii*) ability to read technical French and German an advantage. Posts (*i*) offer opportunities for service abroad. Special short-term appointments are also available at home and abroad for assistance in observations and reduction of results during the International Geophysical Year (1957–8). Salary within ranges: E.O. £875–£1,075; A.E.O. £350 (age 18)–£755. Slightly less for women but subject to improvement under equal pay scheme. Five-day week. Forms from M.L.N.S., Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting A.111/7A. [1071

SERVICE

ASSEMBLY and Winding Capacity Electronic Equipment supervised by technicians experienced in modern technique applicable to computers, V.H.F. and high voltage oscillatory circuits. D.T.V. Contracts Dept., 134/136 Lewisham Way, New Cross, S.E.14. TIDeway 2330. Ext.: 10. [1046

MISCELLANEOUS

CUT wires, pins, special rivets, formed wires, manufactured to specification by Wire Products and Machine Design, Ltd., 20 Bridge Road, Haywards Heath, Sussex. Phone 1990. [1063

AEROMAGIC Receiver, 1935–36 vintage urgently required. Cash available. Also servicing manual. Box 8551. [1076

BOOKS, ETC.

"ABACS or Nomograms." By A. Giet. Translated from the French by H. D. Phippen and J. W. Head. Most engineers have made use of nomograms at some time in their careers, and are fully alive to the fact that they are a very convenient tool when the same formula has to be solved repeatedly for several sets of variables. It is fair to say, however, that only a small proportion of even those who habitually employ nomograms know how to construct them for their own use. Most of the comparatively small literature on the subject is written for mathematicians and is extremely difficult for the practical engineer to comprehend. This book is essentially practical, and not only demonstrates the many and varied applications of the abac or nomogram, but shows how even those without highly specialised mathematical knowledge may construct their own charts. 35*s.* net from all booksellers. By post 35*s.* 10*d.* from the publishers: Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1.

IMPERIAL CHEMICAL INDUSTRIES LIMITED

Metals Division

require

DRAUGHTSMEN

(ELECTRONIC)

for work in connection with the Guided Weapons Programme. The posts afford most varied and interesting work in pleasant surroundings at our Summerfield Research Station, Kidderminster.

Excellent conditions of employment include a Profit-sharing Scheme, a Pension Fund, and a good commencing salary. After joining the staff a married man will receive a reasonable refund of removal (including travel) expenses and, in approved cases, facilities are available to assist in house purchase.

Write for an application form to:

General Services Manager
Imperial Chemical Industries Limited
Summerfield Research Station
Kidderminster

BOOKS, ETC.

"THE Williamson Amplifier." This 15-watt amplifier has gained world-wide recognition on account of its remarkably low distortion. The issues of WIRELESS WORLD in which it was originally described have long since been out of print, and the present booklet, which reprints all the relevant articles from 1947 onwards, gives full details not only of the basic circuit and layout, but also of the ancillary circuits recommended by the designer for high quality reproduction of record and radio programmes. 3*s.* 6*d.* net from all booksellers. By post 3*s.* 10*d.* from Iliffe & Sons, Ltd., Dorset House, Stamford Street, S.E.1.

"RADIO Laboratory Handbook." By M. G. Scroggie, B.Sc., M.I.E.E. This well-known practical work describing laboratory equipment and methods of operation has been entirely rewritten and greatly enlarged. Among the subjects considered are layout and furnishing of premises, methods of measurements, sources of power and signal measurements. There is a comprehensive reference section and many photographs, diagrams, graphs and tables. 25*s.* net from all booksellers. By post 26*s.* 6*d.* from Iliffe & Sons, Ltd., Dorset House, Stamford Street, S.E.1.

"ADVANCED Theory of Waveguides." By L. Lewin. Sets out various methods of treating problems arising in work on this complex subject. The author has selected for discussion a number of topics as representative of the field in which the centimetre-wave engineer is engaged, many of the examples being concerned with the rectangular waveguide. 30*s.* net from all booksellers. By post 30*s.* 10*d.* from Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1.

"RADIO Circuits: Step-by-Step Survey of Superhet Receivers," 3rd Edition. By W. E. Miller, M.A. (Cantab.), M.Brit.I.R.E., Editor of *The Wireless and Electrical Trader.* Although this book deals mainly with the superhet receiver it is equally applicable to the straight set. The circuit of the superhet is dealt with section by section up to the complete receiver. 5*s.* net from all booksellers. By post 5*s.* 7*d.* from Trader Publishing Co., Ltd., Dorset House, Stamford Street, London, S.E.1.

An introduction to the mechanism and applications of computers

from leading booksellers

A book for the technician and business executive

By T. E. Ivall A non-mathematical introduction to the mechanism and applications of computers employing valves and transistors. Both digital and analogue computers are covered, the bulk of the book being devoted to describing their circuitry, while their rapidly developing applications in industry, commerce and science are also outlined. In a final chapter the future evolution of computers is discussed.

165 pp. Illustrated. **25s net** By post 25s 10d

ELECTRONIC COMPUTERS

PRINCIPLES AND APPLICATIONS

Iliffe and Sons Limited · Dorset House · Stamford Street · London SE1

Index to Advertisers

Printed in Great Britain for the Publishers, Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1
by Gibbs & Bamforth, Ltd., St. Albans