ELECTRONIC & RADIO ENGINEER

Incorporating **WIRELESS ENGINEER**

In this issue

Direct-Coupled Amplifiers
Waveguide Design for Die-Casting
Waveform Testing Methods for Television Links
FM-FM Telemetering

Three shillings
and sixpence

DECEMBER 1957 Vol 34 *new series* No 12


ENAMELLED COPPER WIRE
TERAMEL
ENGLAND

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

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.

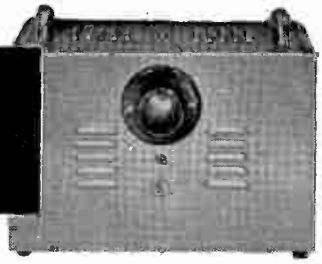
DESIGN SERIES	ASR	ATC	BAVR	BAVR-E	BMVR	TCVR
Input Voltage "Swing"	−10% to +5%	−20% to +10%	−10% to +5%	−10% to +5%	Depends on power: typical is from −19% to +8.5%	
Output Voltage Stability	±2½%	±5%	±0.15%	±0.15%	Usually ±0.5%	Usually ±0.5%
Change due to load (0-100%)	NEGLIGIBLE		±2.0%	±0.3%	NIL	NIL
Harmonics 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.*

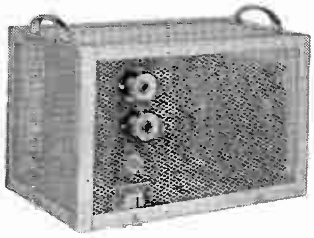
Claude Lyons Ltd.

STABILISER DIVISION

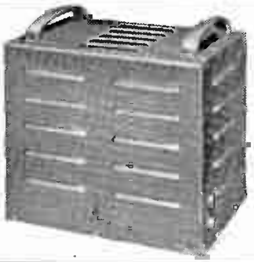
HODDESDON · ENGLAND · TEL: HODDESDON 3007 (4 LINES) · 'GRAMS: MINMETKEM, HODDESDON



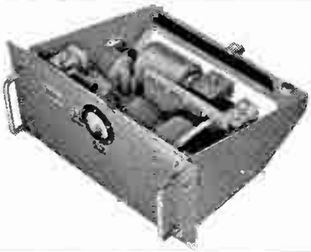
BMVR - 1725



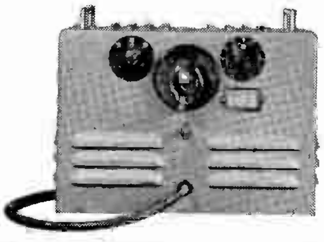
BAVR - 1000 & BAVR - 1000-E



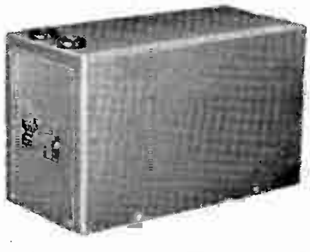
BMVR - 7000 - Series & TCVR - 7000 - Series



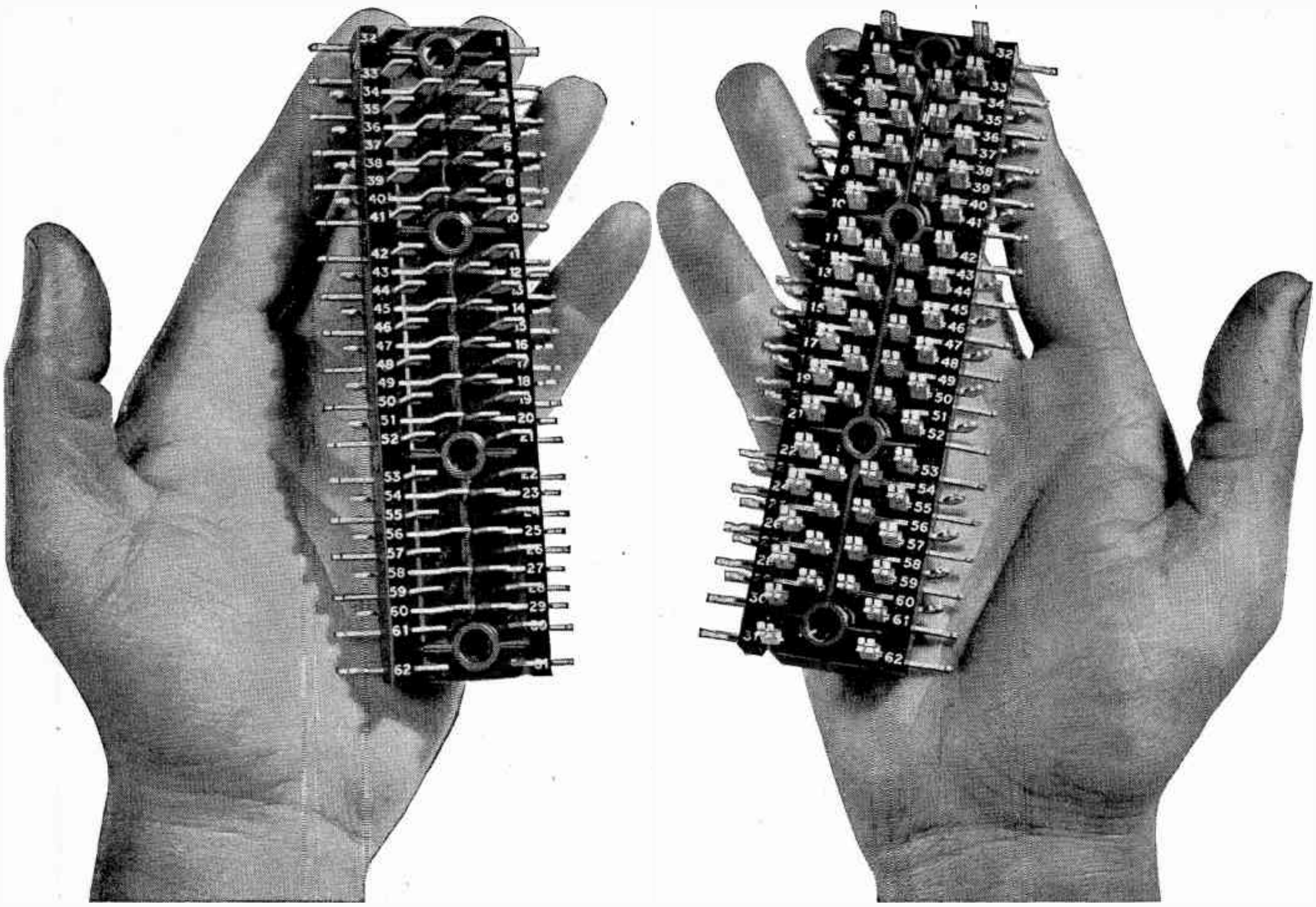
BMVR - 2750 - S58 (AM Ref. 10D 20161)



BMVR - 2750 VV & TCVR - 2750 VV



ASR - 1150 & ATC - 575.



Holding out for good connections?

There are almost certainly enough high grade ones in this 62-way connector. It was designed to fulfil an Admiralty requirement that could not be met by any other connector, and you will find it suitable for many rack-mounting applications where low contact resistance, high voltage and current capacity and excellent insulation are major factors.

SPECIFICATION

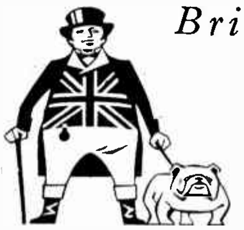
Contact Resistance: less than 3 milli-ohms
Insulation: 2kV. between contacts
Voltage rating: 750V. r.m.s. working
Current rating: 10A. max. per single contact
Insertion pressure: 30 lbs.
Withdrawal pressure: 13 lbs.

31-way connector also available with identical specification except insertion and withdrawal pressures are 20 lbs. and 9 lbs. respectively.

A.I.D & A.R.B — APPROVED
POWER CONTROLS
LIMITED

POWER CONTROLS LIMITED, EXNING ROAD, NEWMARKET, SUFFOLK
Telephone: Newmarket 3181/2/3
Telegrams: Powercon Newmarket


First in the field
V15/10P
V10/10P



When it's a question of Flexibility...

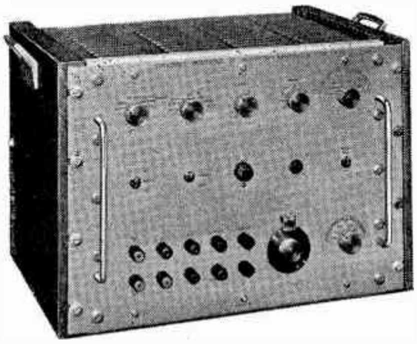
the SERVOMEX L.F.51 low frequency wave-form generator leads the World!

The L.F.51 is an all-British Function Generator of patented design giving a flexibility that has not even been approached by any other instrument. It has now been in production for nearly two years and has been widely adopted for driving analogues and real systems in the United Kingdom and abroad. (Exports, including U.S.A., are over 25% of sales.)

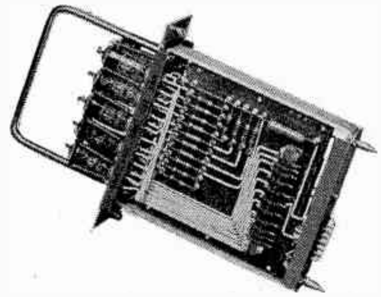
37 Different Waveforms can be generated

SINEWAVES (500C/s down to 1 cycle every 33 minutes)
SQUARE WAVES AND PULSES 100μS to 1,000 secs (rise time 5μS)
RAMPS (lasting 1 millisecond to 1,000 seconds)
Single or repeated pulses of square, triangular, sawtooth, cosine, trapezium shape, sine squared, etc. With modification of 1 unit, a variety of non-standard shapes can be simulated in either single transitions or pulses, e.g. Gaussian.
VOLTAGE 150 volts to less than 100 microvolts peak to peak
LOAD current up to 5mA peak
Four internal stabilised supplies, to maintain frequency and amplitude calibration
Plug-in construction for ease of servicing and compactness
Special synchronising circuit to trigger CRO, etc., in advance of output wave
Decade frequency setting. Balanced (reversing) output

Technical Data Sheets available on request.

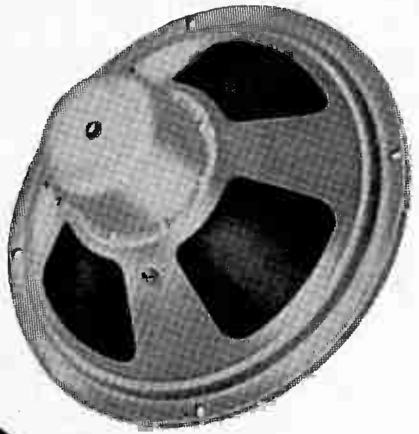


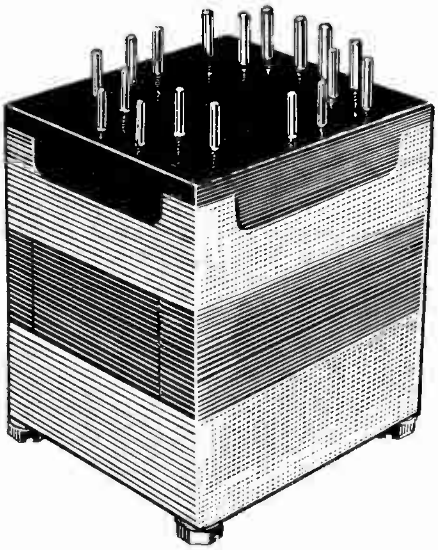
The L.F.51 with wooden ends, removable for use in the 19in. rack.

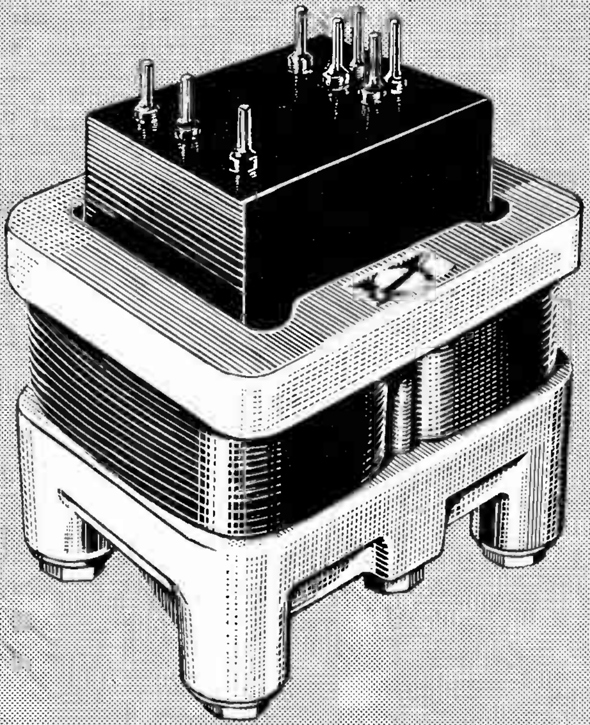


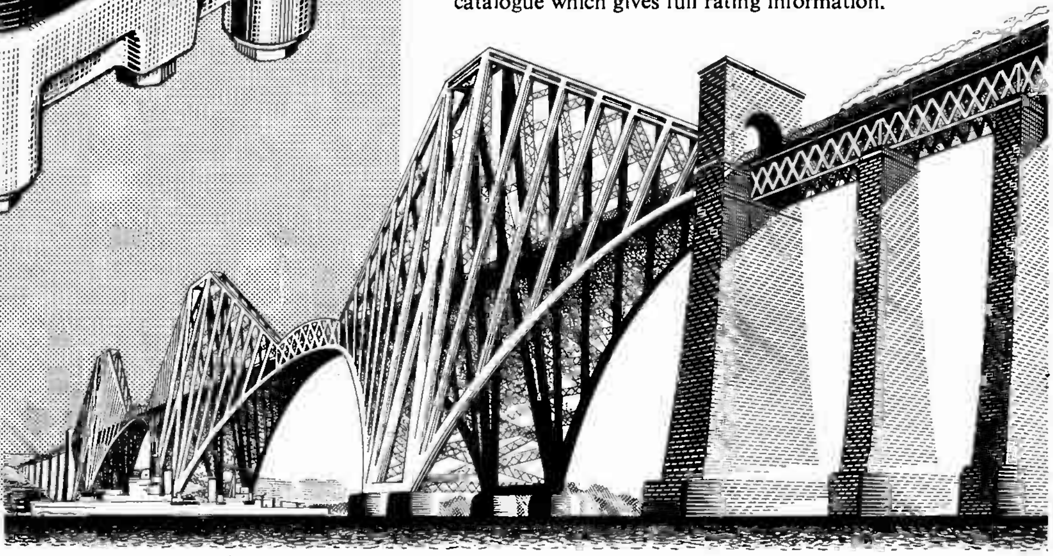
One of the six plug-in units.

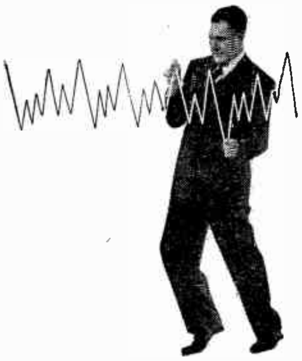
Servomex Controls Limited · *Crowborough Hill* · *Jarvis Brook* · *Sussex* · *Crowborough* 1247



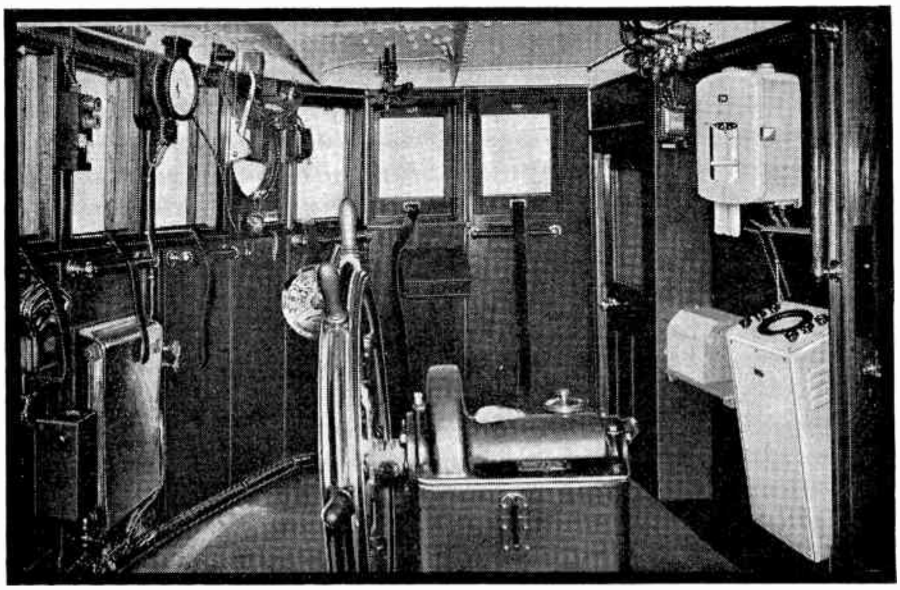








A problem of Fluctuating Voltage Supply in Echo Sounding

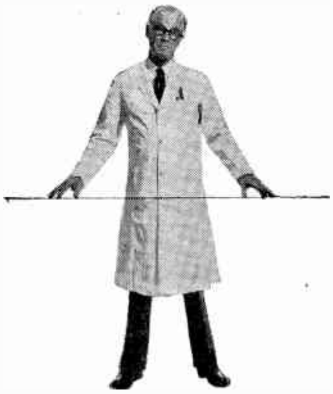


A typical trawler wheel-house showing the Kelvin Hughes Fishing Echo Sounder M.S.29 and KH Kingfisher Scale Expander.

The up-to-date fishing craft carries electronic echo sounders to locate the most promising fishing grounds. This equipment has to cope with supply voltages that fluctuate over a very wide range. In order to obtain reliability, and to *safeguard the life* of electronic components it is essential to stabilise the applied voltage.

How is this achieved . . . ?

. . . straightened out by *Advance*



In the Kelvin Hughes Models M.S.28 and M.S.29 Fishing Echo Sounders, 'Advance' Constant Voltage Transformers are incorporated to ensure reliable long-life performance, even where, as on the smaller vessels, the supply may vary between — 10% and + 30%.

'Advance' Constant Voltage Transformers provide a.c. voltage stabilisation of ± 1% for input variations of up to ± 15% at maximum load. For power requirements from 4 to 6,000 watts, they are automatic and contain no moving parts.

Technical details and descriptive Leaflet R28 gladly sent on request

CVT

CONSTANT VOLTAGE TRANSFORMERS

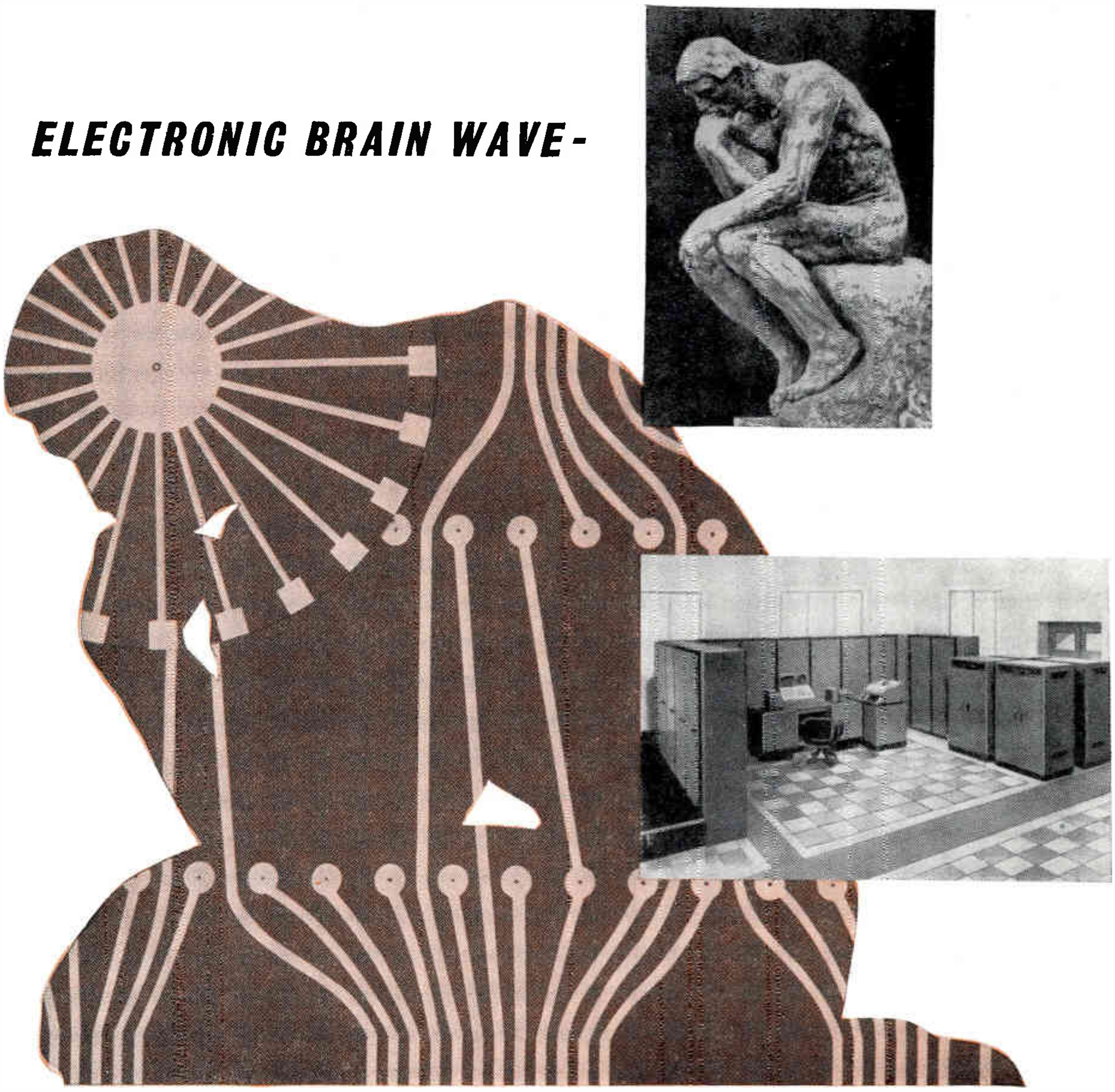
ADVANCE COMPONENTS LIMITED

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

GD.14


Get Cracking!

ELECTRONIC BRAIN WAVE-



with BAKELITE Copper-Clad Laminated

TRADE MARK

The Ferranti Mercury Computer, an immensely powerful machine of enormous capacity, is exceptionally fast and provides facilities for the most advanced techniques of programming. Among many interesting features of this machine is the use of printed circuits produced from Bakelite Copper-Clad Laminated Materials. Used in front to back inter-connected panels and for mounting special pieces of equipment in various parts of the Computer, they reduce the bulk of these assemblies, thus helping to keep down the overall size of the Computer. Reliability provided by printed circuits is of prime importance and their use eliminates the possibility of faulty wiring, thus making servicing and maintenance very much simpler.

Today printed circuits on Bakelite Copper-Clad Laminated Materials, either rigid or flexible, are finding new applications throughout the Radio and Electronics industries. They allow more freedom and precision to the designer, reduce production time and costs for the manufacturer, and give the customer a lighter, more compact and reliable instrument.

Write today for a copy of "Copper-Clad BAKELITE Laminated for Printed Circuits".

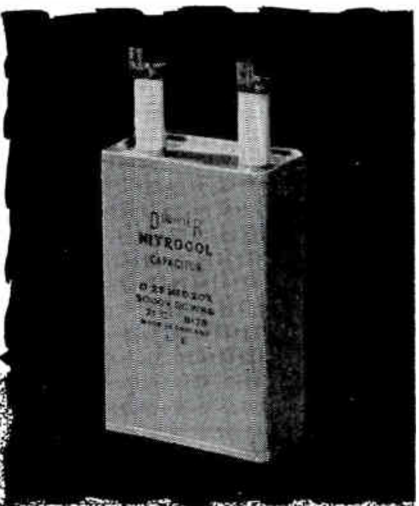
BAKELITE LIMITED

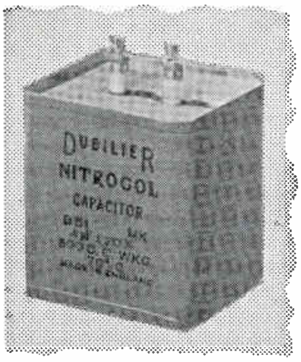
REGD

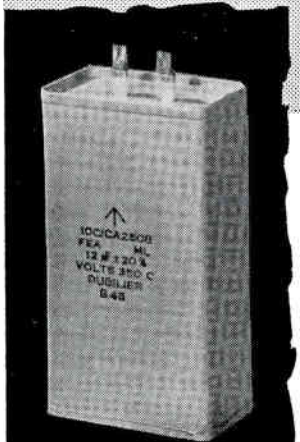
12-18 GROSVENOR GARDENS · LONDON SW1 · SLOane 0898

Bakelite Limited manufacture an extensive range of plastics materials and maintain a technical service unequalled in the industry. No matter what your plastics problems this service is at your disposal. SLOane 0898 is the telephone number.

TGA LP8A

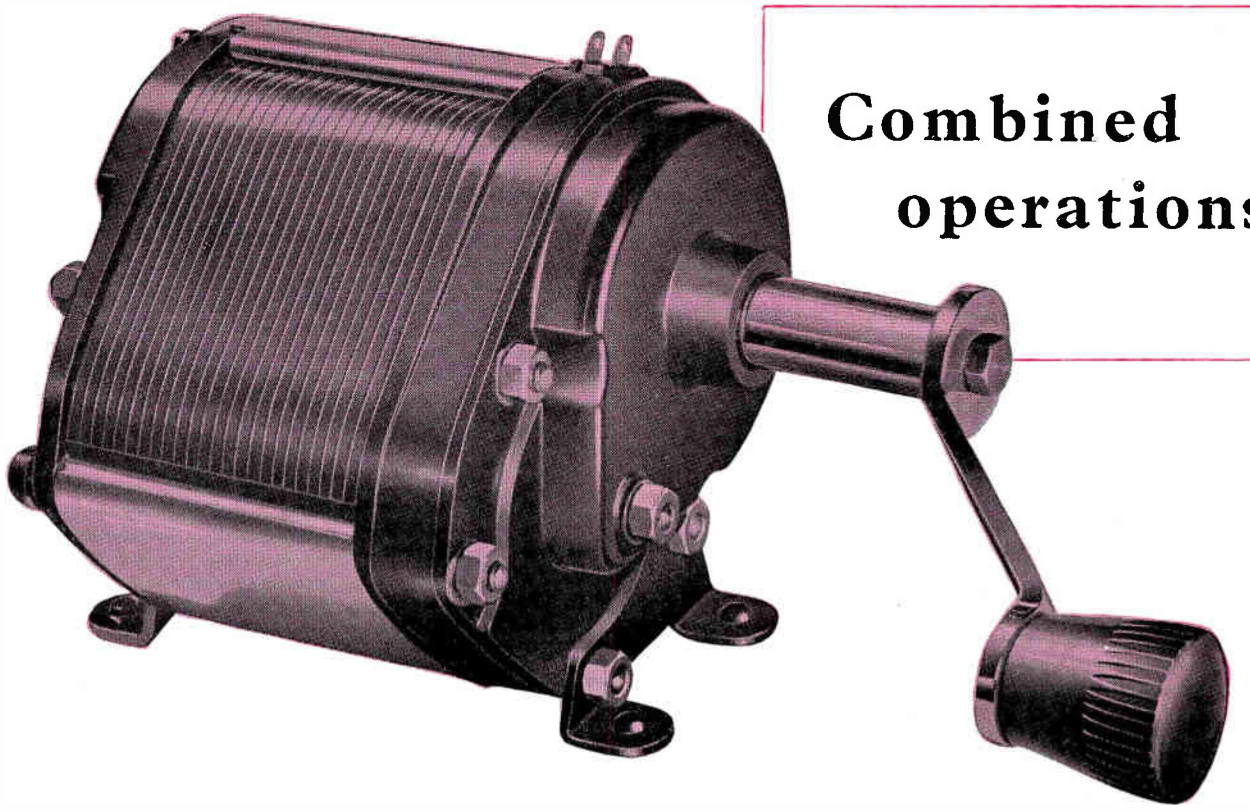

DUBILIER
NITROGOL
CAPACITOR


DUBILIER
NITROGOL
CAPACITOR



In a single application, Araldite epoxy resins combine such diverse functions as bonding, impregnating, insulating and providing surface finishes of remarkable protective value.

This rotating magnet generator, made by Ericsson Telephones Limited for telecommunication equipment, has a greater output than other generators of the same drive torque. It incorporates heavy-gauge iron sheet laminations bolted between diecast alloy end cheeks, and the coil is separately wound on to a moulded bobbin which, when assembled, forms an integral part of the lamination structure. Dimensional accuracy between the end cheeks must be combined with a relatively large dimensional tolerance on the thickness of the laminations, and Araldite Surface Coating Resins have proved indispensable for impregnating the coil, locking the laminations, and imparting an excellent surface finish to equipment which also conforms to tropical specifications.



Combined operations

Araldite epoxy resins are used

- ★ **for bonding metals, porcelain, glass, etc.**
- ★ **for casting high grade solid electrical insulation**
- ★ **for impregnating, potting or sealing electrical windings and components**
- ★ **for producing glass fibre laminates**
- ★ **for making patterns, models, jigs and tools**
- ★ **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

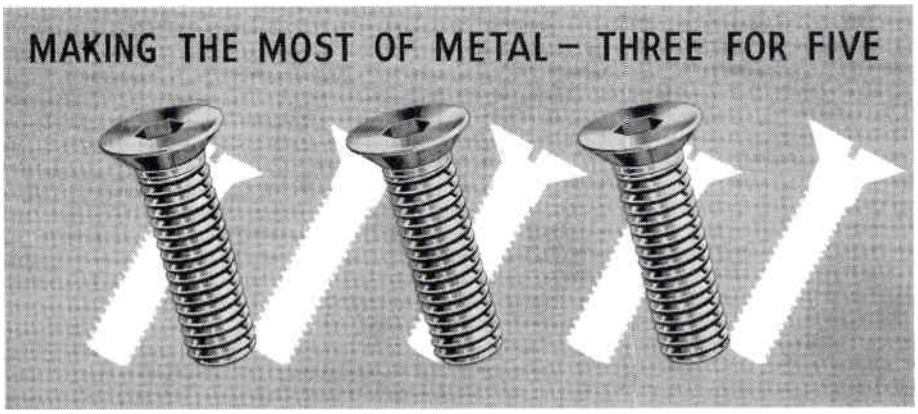
A Ciba Company. Duxford, Cambridge. Telephone: Sawston 2121

AP 321

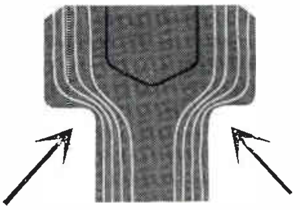
World Radio History

"MAKE IT BIGGER AND HEAVIER SO IT WON'T BREAK"

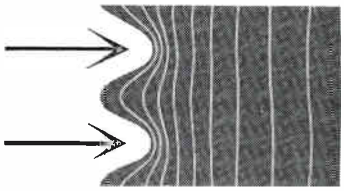
The idea that size means strength was exploded in the Unbrako laboratories years ago. Unbrako designs, Unbrako steels, Unbrako craftsmanship have freed designers from the large and cumbersome fastener, enabling him to use fewer and smaller screws without sacrifice of strength. But Unbrako screws not only save in weight that way, they make practicable weight-saving designs hitherto only dreamed of. Smaller and stronger screws—Unbrako screws—can mean smaller and stronger joints. There's no guesswork about this, we have plenty of examples that we can't go into here, but may we send one of our technicians to talk to you about screws?



Calculating loads and stresses is increasingly important in modern screw design. Machines operate at higher speeds under heavier loads, materials are subjected to greater stresses. Screws are required to do more and better work.

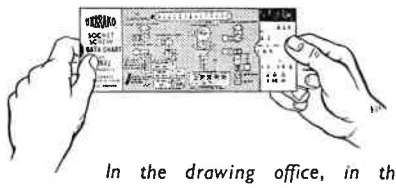


Failure due to repeated stresses on a bolt are located at the point of higher stress concentration. These points are usually the head to shank junction or the threaded section.



With Unbrako, fillets are used at these critical sections to reduce stress concentration and increase fatigue strength, fillets under the head and at the root radius of the thread, carefully controlled for maximum strength.

UNBRAKO SCREWS COST LESS THAN TROUBLE



FREE

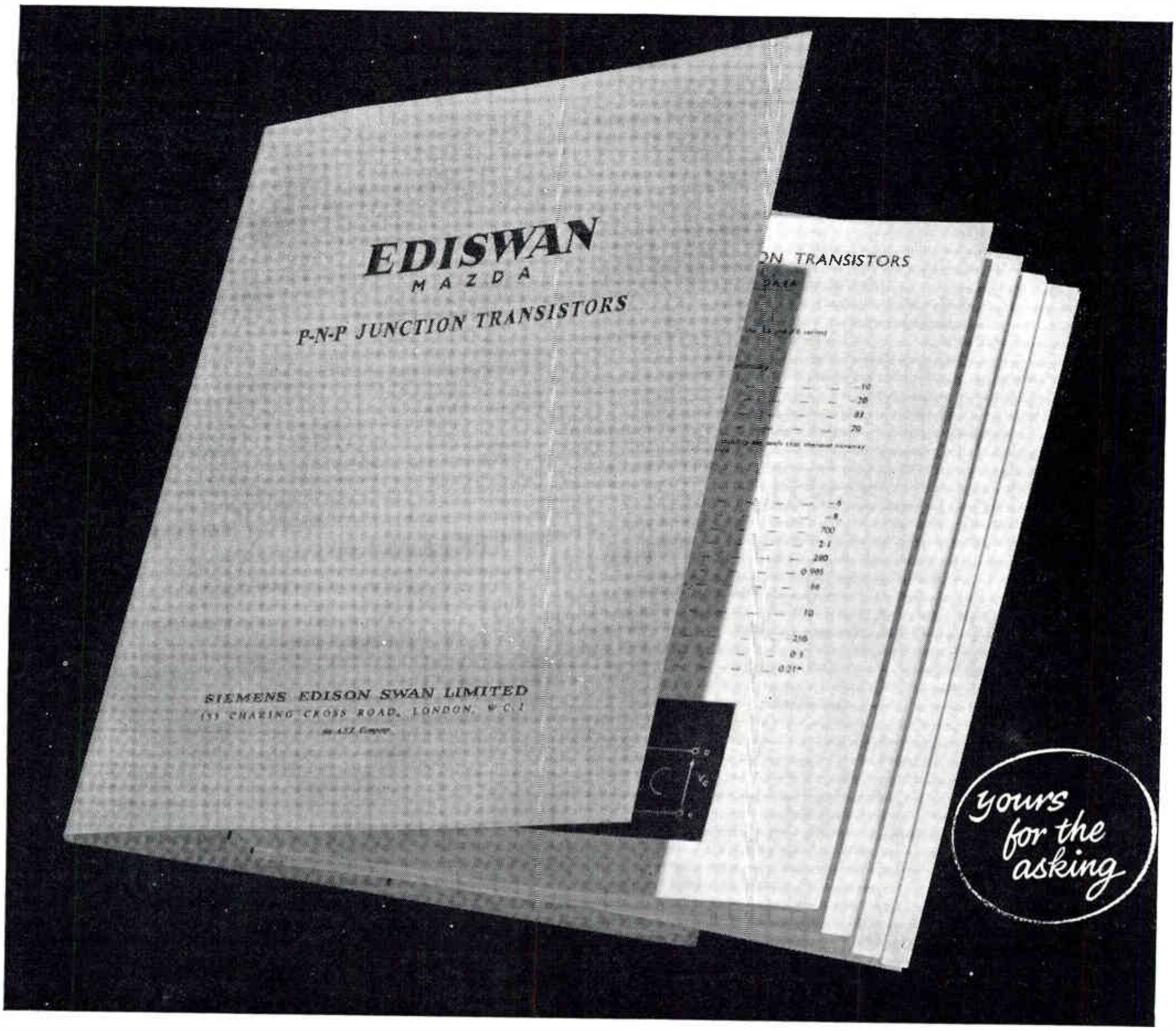
DATA CHART

In the drawing office, in the toolroom or on production — you'll save valuable time and avoid costly guess-work with this free data chart, it cuts out all physical measurements or calculation.

UNBRAKO

THE UNBRAKO SOCKET SCREW COMPANY LIMITED · COVENTRY

World Radio History



EDISWAN transistors

MAZDA

If you are manufacturing or designing electronic equipment you will find this folio of data sheets helpful as a source of reference. It gives you comprehensive information and characteristic curves covering the whole range of EDISWAN Mazda transistors.

Simply ask for the P-N-P Transistor Folio on your business notepaper.

at highly competitive prices

SIEMENS EDISON SWAN LIMITED

155 CHARING CROSS ROAD, LONDON, W.C.2. AND BRANCHES.
TELEPHONE: GERRARD 8660. AN A.E.I. COMPANY.
TELEGRAMS: SIESWAN WESTCENT, LONDON.

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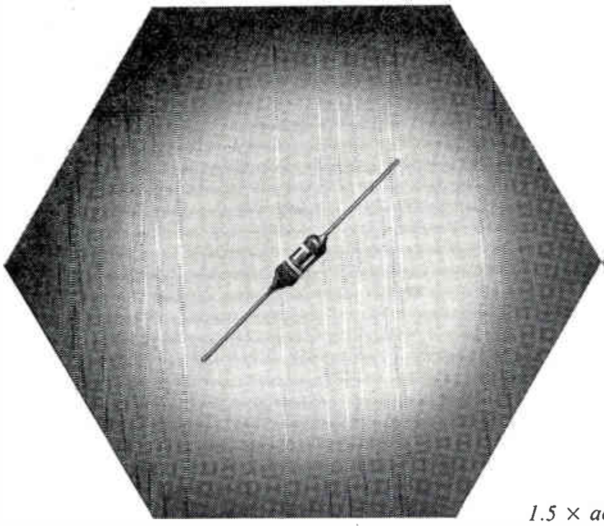
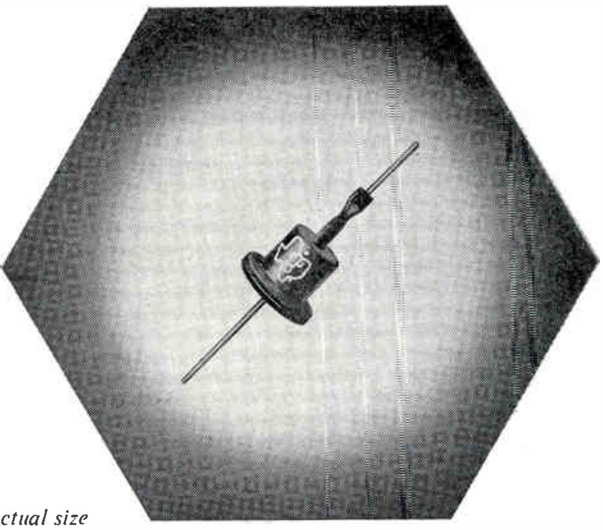




1.5 × actual size

400 mA

" Moly-G ", hard glass hermetically sealed case.
Unit Weight 0.195 Grms.

750 mA

Hermetically sealed metal case.
Unit Weight 1.6 Grms.

NOW AVAILABLE

SILICON RECTIFIERS

200—600 volts P.I.V.

These new 'Texas' Diffused Silicon Rectifiers provide you with :—

High current with high voltage

High Forward to reverse current ratio

Wide operating temperature range

TYPE NUMBERS	Peak Inverse Voltage :	200	300	400	500	600 volts
	Moly G :	1S111	1S112	1S113	1S114	1S115
	Metal Case :	1S001	1S002	1S003	1S004	1S005

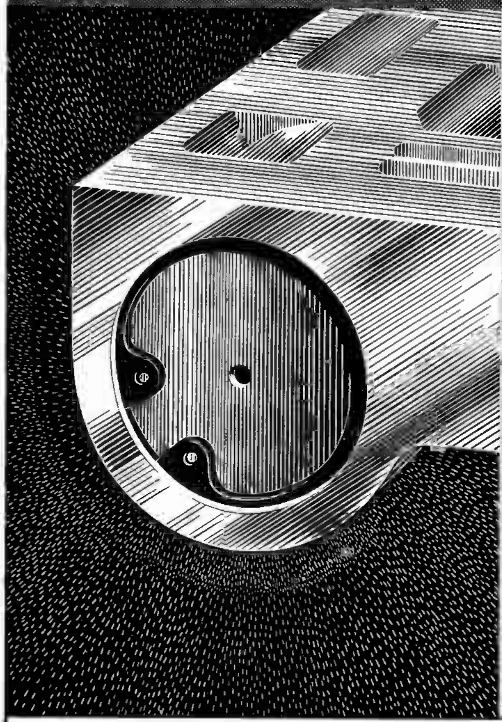
		'MOLY G'	'METAL CASE'	
MAXIMUM RATINGS	Average rectified Forward Current at 25°C	400	750	mA
	Average rectified Forward Current at 150°C	150	250	mA
	Recurrent Peak Forward Current at 25°C	1.25	2.5	Amp.
	Surge Current 1 Sec. D.C. at +25°C to 150°C	3.0	15.0	Amp.
SPECIFICATIONS	Max. Reverse Current at P.I.V. 25°C	0.2	10.0	μA
	Max. Reverse Current at P.I.V. 100°C	15.0	300	μA
	Max. Voltage Drop at I_o=400 mA at 25°C	1.0	1.0	volt

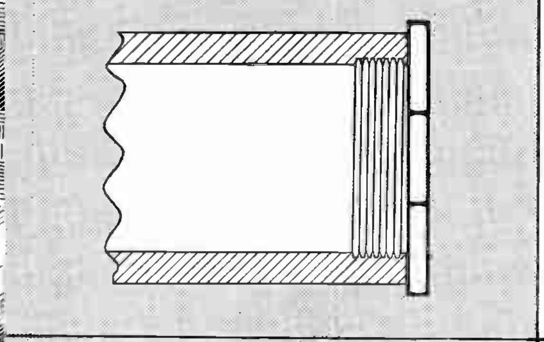
Please write for Data Sheets of these Rectifiers and of our comprehensive range of Silicon Transistors.

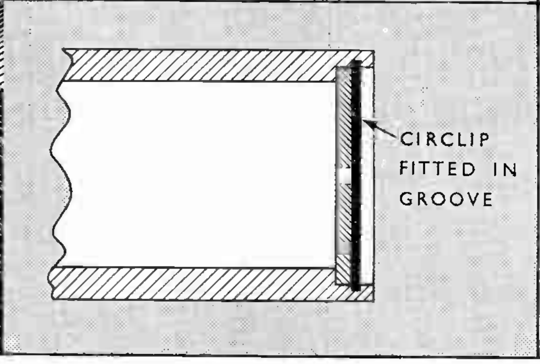
TEXAS INSTRUMENTS LIMITED

DALLAS ROAD · BEDFORD · TEL: BEDFORD 68051 · CABLES: TEXINLIM, BEDFORD

T3






CIRCLIP
FITTED IN
GROOVE

It doesn't matter whether you call it . . .

the **CARPENTER** Polarized Relay

or the Carpenter **POLARIZED** Relay

or the Carpenter Polarized **RELAY**

it is the polarized relay, with the UNIQUE combination of superlative characteristics, that has solved, and is continuing to solve many problems in . . .

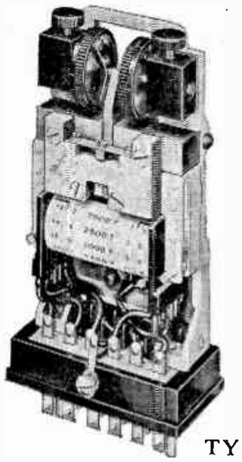
High speed switching · Control
Amplification · Impulse repetition

for : Industrial recording
Aircraft control and navigational equipment
Automatic machine control
Analogue computers
Temperature control
Servo mechanisms
Submarine cable repeaters
Burglar alarm and fire detection equipment
Nuclear operational equipment
Biological research
Theatre lighting "dimmer"
and colour mixing equipment
Teleprinter working
Automatic pilots
Remote control of Radio links
Theatre stage-curtain control
Long distance telephone dialling
V.F. Telegraphy
etc, etc, etc.

Therefore — if your project, whatever it may be, calls for a POLARIZED relay, with high sensitivity, high speed without contact bounce, freedom from positional error, and high reliability in a wide range of temperature variations, *you cannot do better* than use a CARPENTER POLARIZED RELAY.

Write or 'phone for technical data —

TELEPHONE MANUFACTURING CO. LTD.
DEPT. 407, HOLLINGSWORTH WORKS, DULWICH, LONDON, SE21
TELEPHONE: GIPSY HILL 2211



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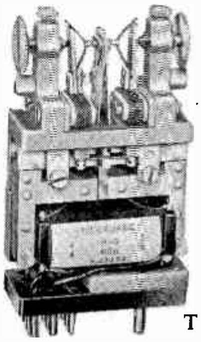

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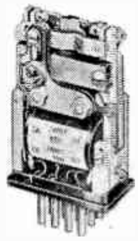
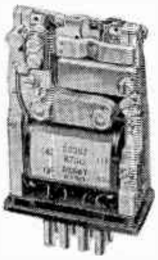


TYPE 5

TYPE 51



TYPE 6

5 Basic types are available each with several variations for special purposes.

World Radio History

NOW!

REALLY ACCURATE WIDEBAND MEASUREMENTS WITH A TOP-QUALITY INSTRUMENT

The superb standards — both in accuracy of measurement and quality of engineering — which have been achieved in the new Solartron Measuring Solarscope CD 643, make this precision-built oscilloscope a *must* for your laboratory.

. . . CHECK THIS BRIEF SPECIFICATION NOW —

Easy-to-read calibrated 'Y' shift.
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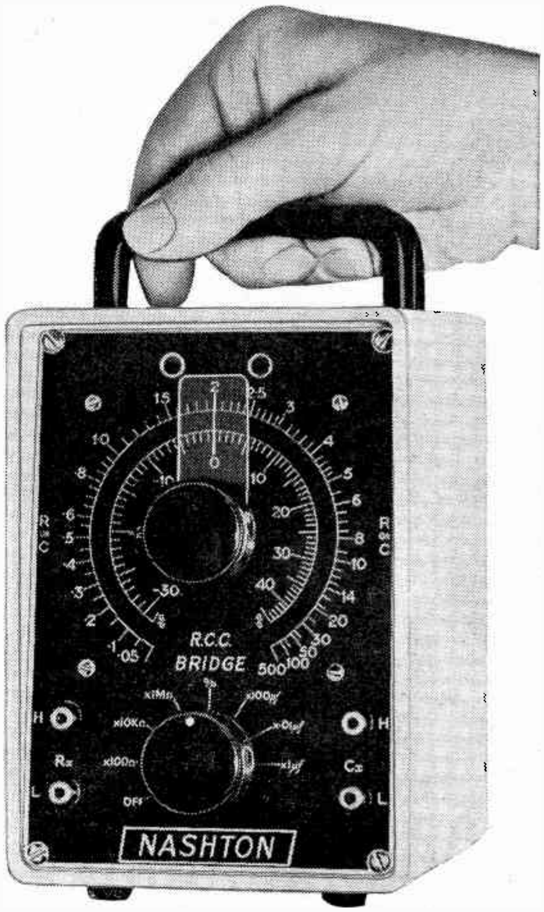

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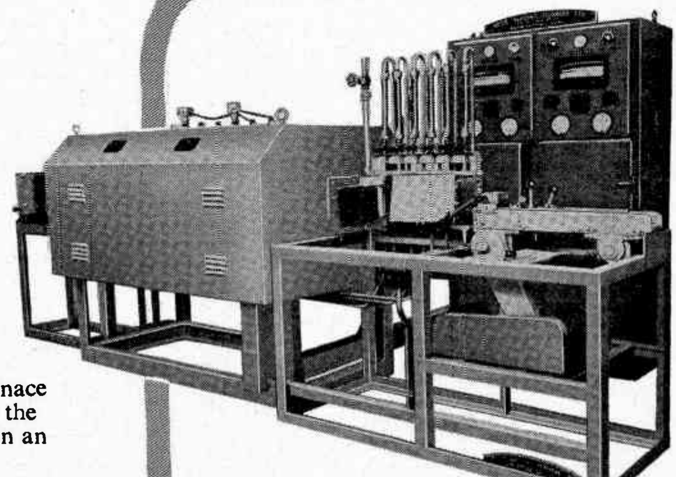

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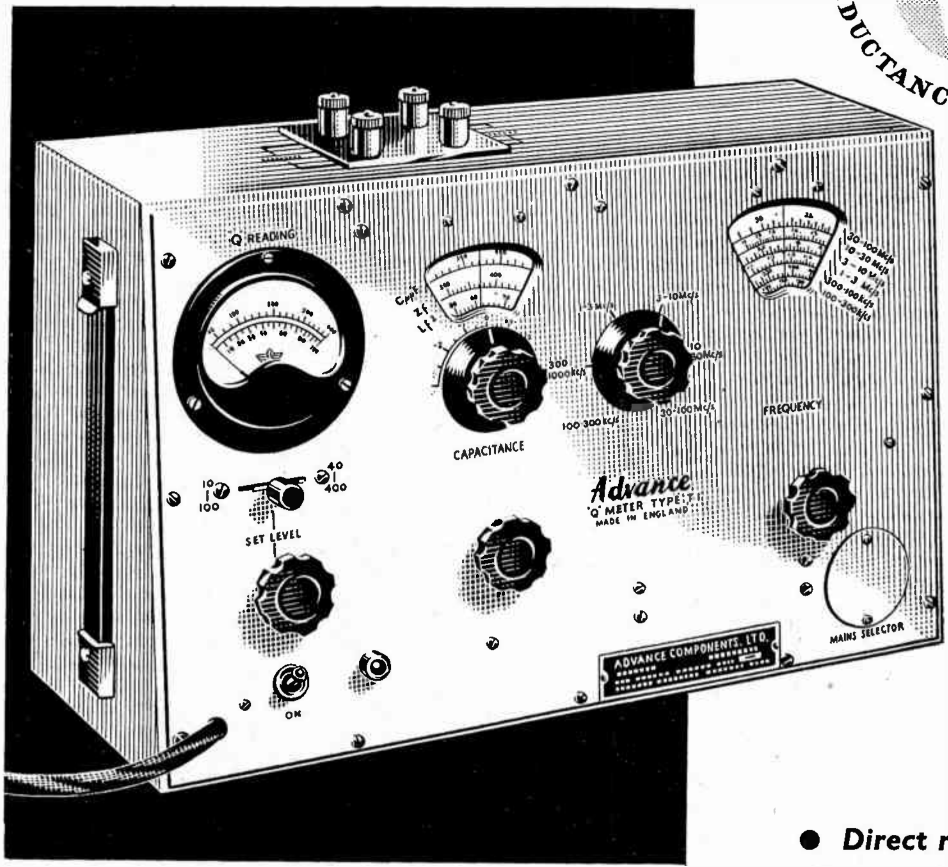

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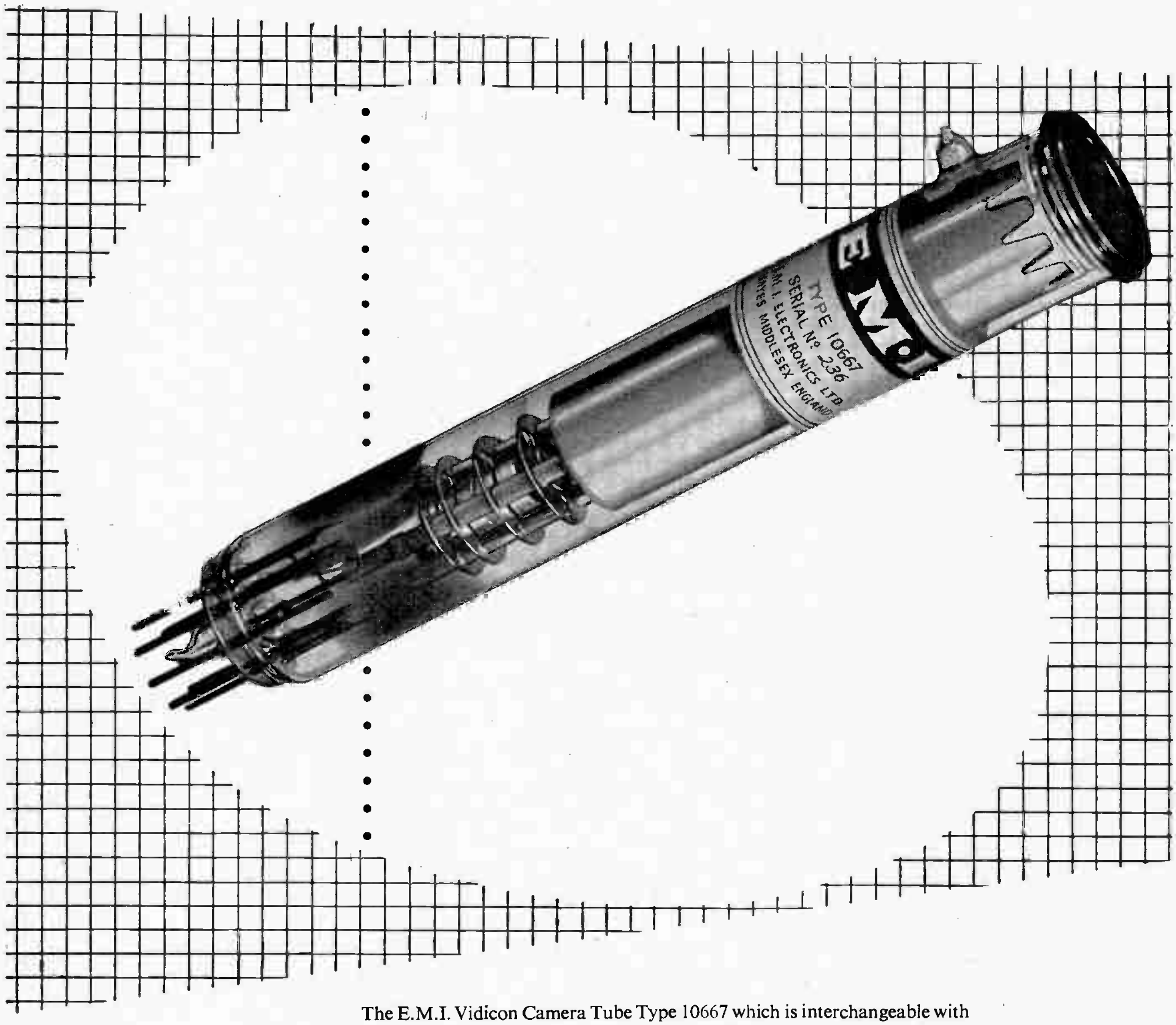

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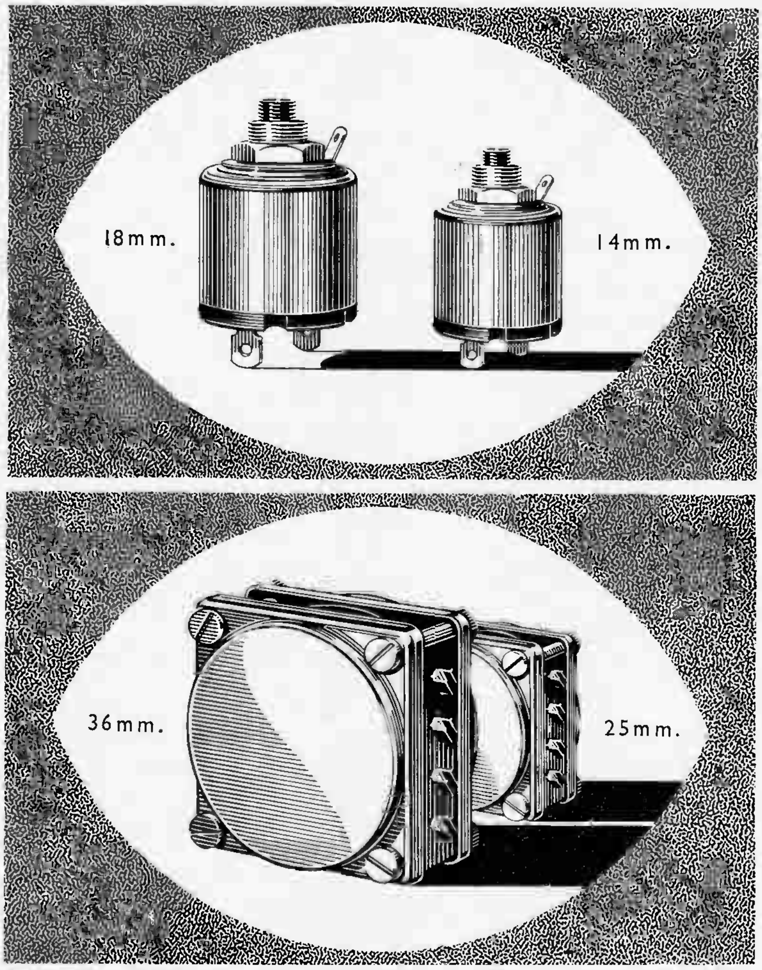

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Television Distortion

IT is always rather a difficult thing to evaluate distortion and to express it by a number. The difficulty is perhaps at its greatest in the case of a television signal, for there are so many quite different ways in which a picture can be distorted. This matter is discussed elsewhere in this issue, where it is shown that certain proposed testing waveforms do permit many different kinds of distortion to be given a numerical designation of magnitude.

We were recently privileged to see a demonstration of the effect of various artificially-introduced distortions, not only upon these test waveforms, but also upon television pictures, mainly of Test Card C. The demonstration was originally arranged by the B.B.C. for the European Broadcasting Union and was later given to members of the Television Society.

The proposed test pulses form a very sensitive method of detecting distortions, for we observed the waveforms were invariably much more affected than the pictures. This is as it should be. On the transmitting side, there can be very many links in the chain of cable and apparatus between the camera and the transmitter. If the overall distortion is to be kept at an acceptably low level, it is necessary to be able to measure exceedingly small amounts if tests on individual pieces of equipment are to be of any value.

The demonstration was very effective in tying together the subjective effect of distortion with its effect on waveform. We regard it as unfortunate that it is impracticable to reproduce photographs of the television pictures. In some cases a moving picture is necessary to assess the subjective effect and that obviously cannot be dealt with by any half-tone illustration. Even with still pictures, however, the degrees of distortion are small and would be largely obscured by the additional distortions of photography, block-making and printing.

Direct-Coupled Amplifiers

IMPROVED BALANCING FACTORS BY MATCHING THE EFFECTS OF HEATER-SUPPLY VARIATIONS

By D. J. R. Martin, B.Sc., A.Inst.P.[*]

SUMMARY. *The article describes a method of artificially matching valves to obtain improved mutual compensation for the effects of normal heater-supply voltage changes. Adjustment is easier than selecting naturally-matched pairs of valves, and considerably better balance is obtained.*

In the design of direct-coupled amplifiers intended for small-signal d.c. amplification, it is usually necessary to take elaborate precautions against the effects of heater-voltage changes in the early stages ; in a typical valve, for example, a change of 1 volt in heater voltage has the same effect on the anode current as a change of 0·2 volt in grid potential. Recourse may be had to voltage stabilization or special drift-correction techniques but, in any case, a worthwhile degree of improvement may be obtained by the use of pairs of valves in balanced circuits in which mutual compensation for these and other undesired changes occurs between valves in a pair. The measure of compensation which may be achieved by this method varies from one valve type to another; it also depends on the possibility of selecting pairs of valves from a batch for their balancing properties. The term 'balancing factor' is used to denote the improvement obtained by using a given pair of valves instead of a single valve and may be defined as the ratio of the mean change in anode current of the pair to the difference between the individual changes for a small change of (in this case) heater-supply voltage.

Methods have been described elsewhere[1–5] for counteracting the effects of heater-voltage changes in individual valves through the introduction of compensating valves which, however, serve no other useful circuit function. In a more general approach, R. E. Aitchison[6] claims that a satisfactory all-round balance—in anode-currents, slopes and heater-supply dependence—can be obtained in a pair of valves by adjustment of the relative heater-voltages for equality of anode currents, other circuit parameters being equalized. Aitchison does not give actual balancing factors, but quotes and concurs with another worker[3] who says that balancing factors greater than 20 are rarely obtained by any method. Aitchison's principle, it may be noted, is not primarily concerned with obtaining high balancing factors against heater-supply variations.

The principle to be described is intended for application to balanced circuits, such as the familiar parallel-balance configuration, where the balancing factor obtainable would otherwise depend on the closeness of matching of selected pairs of valves. It enables an almost perfect balance to be obtained against the effects of heater-supply variations to any given pair of valves of a type; at the same time the other important advantages of a balanced circuit are not precluded and, in fact, the principle may be applied in conjunction with Aitchison's method for an improved general balance.

Matching Principle

The basis of the new principle is the fact that a valve is about twice as sensitive to forced heater-current changes as to heater-voltage changes; this property results from the non-ohmic nature of the heater resistance. For a given (nominal) value of heater voltage, the dependence on supply voltage can be varied over a range of about 2 to 1 by adjustment of the source resistance between zero and infinity. In practice, a much smaller range is sufficient but a means has to be worked out for adjusting the source resistance without appreciably altering the actual working voltage on the heater; this condition may be fulfilled by using a form of bridge circuit.

The circuit for balancing a pair of valves is shown in Fig. 1. If, as will usually be the case, the valves are of the same type their heater resistances will be approximately equal. In these circumstances, R_1 and R_2 should be made equal so that the bridge formed by R_1, R_2, r_1, r_2 is approximately balanced. The voltage V_1 is nominally equal to the intended heater-voltage for the valves. The ratio V_2/V_1 is made approximately equal to R_1/r_1 (or R_2/r_2) so that the voltage appearing across each heater is approximately V_1 and is not appreciably dependent on the setting of R_3. The resistance presented by the source to each valve heater comprises R_1 or R_2 in parallel with the relevant tapped portion of R_3: by adjustment of the position of the slider of R_3, therefore, a differential control is obtained

---

[*] *British Scientific Instrument Research Association, Chislehurst.*

over the sensitivities of the two valves to supply variations, while the actual heater voltages are left relatively undisturbed.

An incidental advantage is to be gained by making the average source resistance presented to a valve heater equal to the average heater-resistance, for long-term changes in heater resistance will then have least effect. The condition for this is

$$\frac{R_1R_3}{2R_1 + R_3} \approx r_1 \text{ (or } r_2\text{)}$$

One further condition is necessary to define the actual values of R_1 (and R_2), R_3 and V_2; it is an arbitrary one, making $V_2 = 2V_1$.

Then $R_3 = 2R_1 = 2R_2 \approx 4r_1$ (or $4r_2$)

On the basis of these relationships, and the previously quoted fact that the heater power is about twice as sensitive to forced current changes as to forced voltage changes, a mathematical examination of the circuit was made and is reproduced in the Appendix. A formula is derived relating the 'natural balancing factor' of a pair to the setting of R_3 required for perfect balance against heater-supply variations; the result is expressed graphically in Fig. 2.

The figure of 2 taken as the ratio of the current and voltage sensitivities is a broad generalization; wide departures from this value will not invalidate the principle but the results derived in the Appendix and illustrated in Fig. 2 should only be regarded as typical.

In the system as described so far the working heater voltages on the valves are equal, by virtue of R_1 being equal to R_2. It is possible, however, to vary the actual voltages over a fairly wide range by adjustment of R_1 and R_2 and, if necessary, by unbalancing them; this does not detract from the balancing properties of the circuit but some readjustment of R_3 is usually necessary after R_1 or R_2 has been altered. This facility renders the principle fully compatible with Aitchison's method for obtaining an improved all-round balance for, by making R_1 and R_2 differentially variable, the individual heater voltages may be adjusted for equality of anode currents. On the other hand, it is in some ways preferable to keep the heater voltages as closely matched as possible so that the cathodes are at approximately the same temperature: the thermal lags are then more likely to be similar and long-term stability probably improved also. By allowing a restricted adjustment of R_1 and R_2 it is possible to obtain a close balance of thermal time-constants of the two heater-cathode assemblies. Exact balance is not always obtainable because there are, in fact, two time constants in each valve to be considered—that associated with the heater resistance and that with the emission—and a simultaneous balance of these may not be possible; but the residual discrepancy is usually very slight.

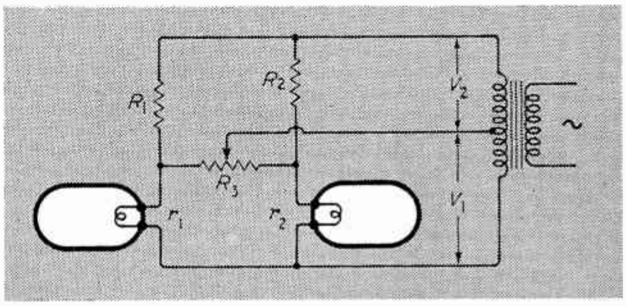

Fig. 1. *Circuit for matching a pair of valves*

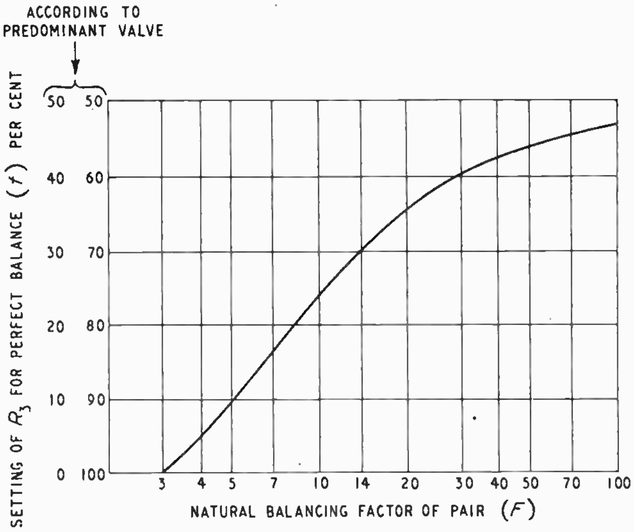

Fig. 2. *The setting of R_3 for values of the natural balancing factor. The curve is theoretically derived (see Appendix), based on the assumption that valves are twice as sensitive to heater-current changes as to heater-voltage changes*

Experimental Results

The improvements in balancing factors obtainable are exemplified by the results given in Table 1. It will be seen that balancing factors in excess of 100 are easily obtainable with any pair of valves. Actual values are not given over 100 as it is extremely doubtful whether improvements on this figure have any practical significance in view of the inevitable small changes which occur in valves from time to time.

The balancing factors have all been measured for input supply changes of ± 8%. The adjustment is dependent on anode current but usually holds good over a range of ± 10% of the mean value. Doubling or halving the anode current usually fails to reduce the balancing factor below 20.

Although the results shown were obtained with pentodes, the system is, of course, equally applicable to triodes. The noval-based double triodes in the ECC81-2-3 series are particularly suitable by reason of their centre-tapped heater connections, enabling a match to be obtained between two valves in the same envelope.

Practical Notes

The most straightforward method of adjustment is to connect a microammeter between the anodes of the valves concerned and to equalize the anode currents by means of a differential potential on the grids or by such equalizing control as may be provided in the particular circuit. A step change in heater supply voltage should then be made and the microammeter reading noted when thermal equilibrium is again reached. If one valve proves to be more sensitive to supply variations than the other, the slider of R_3 should be moved closer to the end connected to that valve and the trial repeated. To facilitate adjustment at any time, the transformer supplying the heaters should have a tap-changing switch in the primary so that a small step change of, say, 5 or 10% can easily be made; this switch could be incorporated with the mains-voltage adjustment. In many cases the microammeter will be superfluous, satisfactory indication being obtained on a meter already present in the amplifier. It is an advantage if R_3 is fitted with a graduated scale, as this speeds up adjustment procedure by allowing extrapolation and interpolation. Also, if spare valves are to be supplied with the equipment for replacement by unskilled personnel, the correct adjustment may be previously determined and noted for reference.

If the additional facility of close time-constant balance is required, the ends of R_1 and R_2, instead of being joined together, should be returned to the two ends of a small potentiometer, the slider of which is connected to the transformer in place of the previously-commoned ends of R_1 and R_2. The first adjustment should always be for steady-state balance, with the slider of the above-mentioned potentiometer at the half-way position. If, then, one valve is found to respond more quickly than the other to changes, the heater voltage to that valve should be reduced by turning the new control in the appropriate direction and a fresh trial made. It is usually necessary to restore the steady-state balance each time the heater voltages are altered; it is always necessary, of course, to equalize the anode currents afresh.

The resistors R_1 and R_2 should be rated at twice the power of the heaters and should have good stability. Potentiometer R_3 dissipates negligible power and a 3-watt wire-wound component is more than adequate. Likewise, the thermal-balancing potentiometer, if included, may be a small component.

Finally, it may be remarked that the method is not restricted to the matching of pairs of valves. If potentiometer R_3 is replaced by a separate variable resistor for each valve, the principle may easily be extended to enable any number of valves to be matched ; in fact the particular application for which the method was first developed requires the matching of three valves in this way.

TABLE 1

Balancing Factors obtained on two types of valve

Valve Type EF37A			
Valve pair	Anode current (mA)	Natural balancing factor	Modified balancing factor (adjusted at 0·5 mA)
1 and 2	0·25	12	50
	0·5	16	>100
	1·0	15	>100
2 and 3	0·25	16	30
	0·5	36	>100
	1·0	70	70
3 and 4	0·25	13	25
	0·5	25	>100
	1·0	100	30
1 and 3	0·25	7	17
	0·5	11	>100
	1·0	13	>100
2 and 4	0·25	7	14
	0·5	15	>100
	1·0	40	25
1 and 4	0·25	5	12
	0·5	8	>100
	1·0	11	30

Valve Type 6J7GT			
Valve Pair	Anode current (mA)	Natural balancing factor	Modified balancing factor (adjusted at 0·5 mA)
1 and 2	0·25	35	33
	0·5	17	>100
	1·0	20	>100
2 and 3	0·25	>100	>100
	0·5	50	>100
	1·0	>100	>100
4 and 5	0·25	12	24
	0·5	8	>100
	1·0	6	24
2 and 4	0·25	10	16
	0·5	6	>100
	1·0	5	30
2 and 5	0·25	25	>100
	0·5	20	>100
	1·0	40	40
1 and 5	0·25	80	80
	0·5	>100	>100
	1·0	40	40

Acknowledgement

Thanks are due to the Council and Director of the British Scientific Instrument Research Association for permission to publish this paper.

REFERENCES

[1] M. Artzt, "Survey of D.C. Amplifiers", *Electronics*, Vol. 18, August 1945, p. 112.

[2] "Vacuum Tube Amplifiers", M.I.T. Radiation Lab. Series No. 18, McGraw-Hill, 1948.

[3] C. M. Verhagen, "A Survey of the Limits in D.C. Amplification", *Proc. Inst. Radio Engrs*, Vol. 41, May 1953, p. 615.

[4] J. Yarwood and D. H. Le Croissette, "D.C. Amplifiers. Methods of Amplifying and Measuring Small Direct Currents and Potentials", *Electronic Engng*, Vol. 26, 1954, p. 14.

[5] R. E. Aitchison, "The Selection of Triode Valves and Circuits for Direct Coupled Amplifiers", *J. Instn Engrs Aust.*, Vol. 27, December 1955, p. 339.

[6] R. E. Aitchison, "A New Circuit for Balancing the Characteristics of Pairs of Valves", *Electronic Engng*, Vol. 27, May 1955, p. 224.

APPENDIX

Mathematical Examination of the Principle

To establish first the effect of source resistance on sensitivity to heater-supply variations (Fig. 3) :

By inspection of diagram $V = i\,(R + r)$ .. .. .. (1)

and $v = ir$ . .. . (2)

By differentiation of (1) $\delta V = (R + r)\,\delta i + i\delta r$ .. .. (3)

By differentiation of (2) $\delta v = i\delta r + r\delta i$ .. .. .. (4)

Expressing property of heater (used as basis of principle)

$$\frac{\delta v}{v} = \frac{2\delta i}{i} \quad .. \quad .. \quad .. \quad .. \qquad (5)$$

Dividing (4) by (2) and comparing with (5) gives

$$i\delta r = r\delta i = \frac{\delta v}{2}$$

Substituting in (3) gives $\delta V = (R + r)\,\dfrac{\delta v}{2r} + \dfrac{\delta v}{2}$

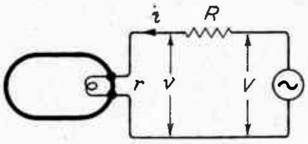

Fig. 3

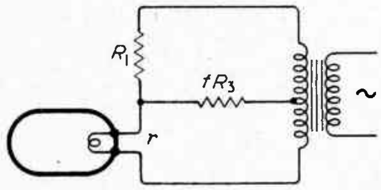

Fig. 4

Figs. 3 and 4. *Simplified circuits for one valve*

By putting $\frac{R + r}{r} = \frac{V}{v}$ [from dividing (1) by (2)] we may obtain

$$\frac{\delta v}{v} \Big/ \frac{\delta V}{V} = \frac{2\,(R + r)}{R + 2r} = \text{(say) } n \quad \cdots \quad (6)$$

This ratio, for convenience denoted by n, represents the increase in sensitivity of the heater on account of the source resistance R.

Referring now to Fig. 4, which shows the relevant portion of Fig. 1 for one valve, the source resistance R is represented by R_1 in parallel with fR_3, where f is the tapped fraction of R_3 relevant to the valve;

$$\text{i.e., } R = \frac{fR_3R_1}{fR_3 + R_1}$$

subsituting in (6) $n_1 = \dfrac{2(fR_3R_1 + fR_3r + R_1r)}{fR_3R_1 + 2fR_3r + 2R_1r} \quad \cdots \quad (7)$

the suffix ($_1$) being added to identify it with the valve.

If $R_1 = 2r$ and $R_3 = 4r$, as recommended in the text, (7) reduces to

$$n_1 = \frac{6f + 1}{4f + 1}$$

For the other valve the relevant portion of R_3 will be $(1 - f)\ R_3$

therefore $n_2 = \dfrac{6\,(1 - f) + 1}{4\,(1 - f) + 1} = \dfrac{7 - 6f}{5 - 4f}$

If the valves themselves are perfectly matched then the balancing factor of the circuit will be

$$\frac{\frac{1}{2}\,(n_2 + n_1)}{n_2 - n_1}$$

Conversely, if the valves themselves are imperfectly matched, with a natural balancing factor of F, then the value of f required to achieve perfect balance is given by

$$F = \frac{\frac{1}{2}\,(n_2 + n_1)}{n_1 - n_2}$$

Substituting for n_1 and n_2 in terms of f and simplifying gives

$$F = \frac{3\,(1 + 4f - 4f^2)}{1 - 2f} \quad \cdots \quad (8)$$

This relationship is plotted in Fig. 2.

Waveguide Design For Die-Casting

ALLOWING FOR WALL TAPER

By P. Humphreys, B.Sc., Grad. Inst.P.*

SUMMARY. *This article explains how components which have been designed in normal rectangular waveguide may be easily modified on a theoretical basis to make them suitable for die-casting manufacturing methods. The theory is applicable to cases where the waveguide can be manufactured by splitting it along the length of the central E-plane and the unit is therefore cast in two halves.*

In recent years many methods have been suggested for the manufacture of microwave components. The original methods of fabrication are no longer favoured because they are costly and require accurate soldering and complicated assembly jigs if a consistent product is to be maintained. In addition, where a fabricated guide has been machined to make, for example, a T-junction, the application of sufficient heat for brazing will cause distortion of the waveguide sections in spite of periodical annealing. Many methods for simplifying the manufacture of microwave components involve splitting the waveguide along its length in the central E-plane. This is satisfactory since there are no waveguide wall currents in this plane. The component is thus made in two halves which are fixed together during assembly. One method which uses this technique is pressing and, with small and simple components, accuracies within 0·003″ are possible on a 0·900″ by 0·400″ (W.G.16) cross-section waveguide. It is, however, often necessary to use several processes and to press the corners specially to form the correct shape. A disadvantage comes if a complete component assembly is required since, in general, there is not sufficient material available to press all the channels from a thin blank. In these cases, hot or cold hobbing has been suggested and preliminary results have shown that such a method is capable of giving good surface finishes. Sometimes the metal will not flow satisfactorily

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to form a complicated unit without the application of such extremes of pressure as would cause damage to the tool, and the method is not applicable where very thin wall sections are required.

A common method is to mill the two halves of the microwave unit from metal blocks or from rough castings. Normally, milling is expensive, but copy milling can, if the right machine is available, be carried out quite economically and accuracies of better than 0·002″ are obtainable by this method.

Another alternative which is being investigated is that of stamping out the sections of the waveguide which are then fixed together, sometimes by making them self-jigging, and the complete assembly is dip-brazed ; this makes a very light unit.

The cheapest manufacturing method is that of casting and much general experience is available. Sand castings alone are incapable of giving sufficient accuracy for general microwave work and must, therefore, be machined. Castings on disposable mandrels ; i.e., the lost wax, plaster casting, or Mercasting processes, have been used with a fair degree of success and, in general, tolerances of 0·003″ per inch are attainable ; with these types of castings it is often unnecessary to split the unit into two halves. By their nature, however, and the number of processes which are involved, such castings are more expensive than pressure or gravity die-castings.

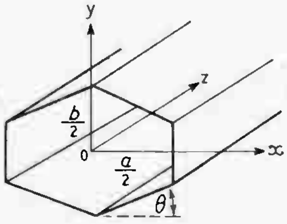


Fig. 1. *Hexagonal waveguide*

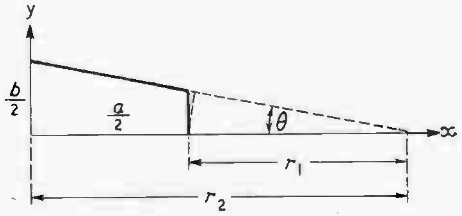


Fig. 2. *Radial waveguide*

Die-castings of centimetric components have been made in Mazak and in light alloys. At first sight, Mazak appears to be an ideal material since it will cast extremely cleanly with a good surface finish, and a taper of about 0·003″ per inch per side of the tool (corresponding to an angle of 10 minutes), or even less, is quite adequate. The electrical resistivity of Mazak is not sufficient to eliminate its use for items such as r.f. heads, but the material suffers from lack of corrosion resistance (especially to salt water) and is also very brittle if there is the slightest trace of poisoning from other metals, such as cadmium. Although Mazak can be protected by chromating or plating, or by varnishing, and although the material can be made free from poisoning, its use is not generally advocated for Service requirements.

Aluminium and some light-alloy die-castings can be made free from brittleness, and can be protected quite adequately by processes such as anodizing. The disadvantage of light-alloy die-castings is that they require a considerable taper before they can be removed from the tool, whereas with Mazak only a small taper is necessary. To obtain satisfactory removal from the tool waveguide units are usually cast in two mating halves, similar to Fig. 6, which are joined along the E-plane centre line of the waveguide, also allowance must be made for the hexagonal form of the waveguide cross section. An effective taper is also useful for components made by electroforming or metal spraying on to non-disposable mandrels. Cast-aluminium rat races have been made in waveguide equivalent to W.G.16, which have tapers of ½° (or 0·009″ per inch) per side, but these are difficult to remove from the tool. Alternative angles of the taper (θ, Fig. 3) which have been suggested are 1½°, 2½° and 5° per side. It is considered that to adopt the 5° (or 0·087″ per inch) taper is advantageous for two reasons. First, since the quantity of microwave components required is much smaller than that normally produced by die-casting processes, manufacturers are often reluctant to undertake waveguide castings, so that, the easier the job is made for them, the more likely they are to undertake the work. Secondly, there are some cases in which it is easier to design the unit electrically if some planes orthogonal to the main waveguide run are vertical ; e.g., with transformers and where the main waveguide run turns through a right-angle, thus effectively halving the overall taper. In addition, since a new waveguide cross-section has to be developed, it is no more difficult to develop one which has a 5° taper than one with a smaller taper. For all these small angles, there is no fear of modes other than the dominant mode arising in the waveguide.

It is obvious that a hexagonal waveguide section can be established arbitrarily merely by tapering the waveguide walls. Such a section is not satisfactory since lengths of standard rectangular waveguide and valves requiring standard waveguide apertures have to be used with the die-casting. Thus it is advantageous to design the hexagonal waveguide section so that it will have the same impedance and cut-off wavelength as a standard rectangular waveguide ; any mismatch between the two waveguides will then be reduced to a small susceptive one. Such a junction has been found to have a reflection coefficient less than 0·005.

Theoretical Treatment of Hexagonal Waveguide

Cut-Off Wavelength by Variational Method

For a waveguide of arbitrary cross-section, there is a general relationship between the cut-off wavelength, λ_c, and the shape of the cross-section[1] given by:

$$\frac{\int_S \left\{ \left(\frac{\delta V}{\delta x}\right)^2 + \left(\frac{\delta V}{\delta y}\right)^2 \right\} dS}{\int_S V^2 \cdot dS} = \left\{\frac{2\pi}{\lambda_c}\right\}^2 \quad \ldots \quad \ldots \quad (1)$$

where the integrals are taken over the cross-section S of

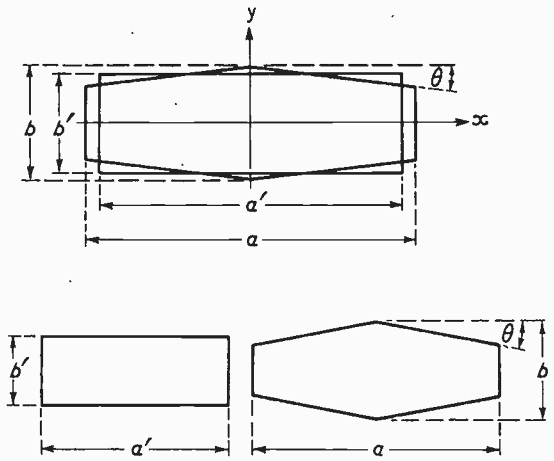


Fig. 3. *Equivalent rectangular and hexagonal waveguide*

the waveguide; V represents either E_z or H_z, where z is the direction of propagation.

This is a variational expression, so that the function V that results in the maximum value of λ_c is the correct value which satisfies the wave equation and the boundary conditions. Thus, if an arbitrary function V is tried, the value of λ_c arrived at will always be smaller than the correct solution.

Consider a hexagonal waveguide as shown in Fig. 1. For this waveguide the dominant mode approximates to that of a rectangular guide in its dominant mode and

$$V = H_z \approx \sin \frac{\pi x}{a} \quad \cdots \quad \cdots \quad \cdots \quad (2)$$

Substituting this in Equ. (1) and integrating between the limits of the waveguide cross-section gives

$$\frac{4a^2}{\lambda_c^2} = \frac{1 - \dfrac{a\theta}{b}\left\{\dfrac{1}{2} - \dfrac{2}{\pi^2}\right\}}{1 - \dfrac{a\theta}{b}\left\{\dfrac{1}{2} + \dfrac{2}{\pi^2}\right\}}$$

which may be rewritten as:

$$\left(\frac{\lambda_c}{2a}\right)^2 = 1 - \frac{1}{\dfrac{\pi^2}{4} \times \dfrac{b}{a\theta} - \dfrac{\pi^2}{8} + \dfrac{1}{2}} \quad \cdots \quad \cdots \quad (3)$$

For the equivalent rectangular guide $\lambda_c = 2a'$ (Fig. 3).

Thus if the guide dimensions are known, the cut-off wavelength may be calculated. For example, a hexagonal waveguide, with a width of 1·174″, a height of 0·525″ and a taper angle of 5° had an experimental cut-off wavelength of 2·244″; i.e., identical with that of 1·122″ × 0·497″ aperture cross-section waveguide (W.G.15).

Putting these dimensions in the above expression, $a\theta/b = 0{\cdot}1951$, giving $\lambda_c = 2{\cdot}247''$. This figure is less than the correct value of λ_c owing to the variational nature of the expression, but cannot be far from the correct value since it is already slightly greater than the experimental figure. This discrepancy may be attributed to experimental error. Alternatively, it has been suggested[2] that Equ. (1) is variational for trial functions V only if these always satisfy the boundary conditions. The variational approach then also establishes which function satisfies the wave equation.

Alternative Theories for the Cut-off Wavelength

These theories make use of the property that, at cut-off, the cross-section of the waveguide forms a resonator in which half the cross-section has the electrical length of a quarter wavelength.

A theory developed by Marks and Gouldson[3] regards the half cross-section as a slightly non-uniform transmission line. By utilizing the resonant wavelength of a slightly non-uniform transmission line as given by Schelkunoff[4], they obtain

$$\frac{\lambda_c}{2a} = 1 - \frac{\displaystyle\int_0^{\frac{a}{2}} y \,.\, \cos \frac{2\pi x}{a} \,.\, dx}{\displaystyle\int_0^{\frac{a}{2}} y \,.\, dx}$$

which reduces to

$$\frac{\lambda_c}{2a} = 1 - \frac{1}{\dfrac{\pi^2}{2}\left\{\dfrac{b}{a \,.\, \tan\theta} - \dfrac{1}{2}\right\}} \quad \cdots \quad \cdots \quad (4)$$

The similarity to the variational Equ. (3) is apparent.

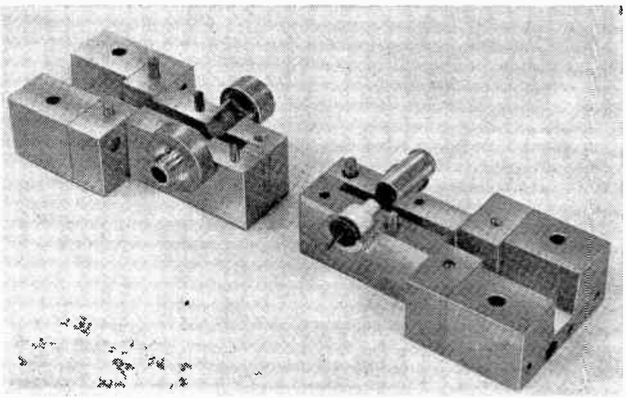
Substituting the above guide dimensions in this expression gives $(a \tan \theta)/b = 0{\cdot}1956$ and $\lambda_c = 2{\cdot}245''$. It is worth noting that the Ministry of Supply report assumes that second-order terms in the denominator may be neglected, which is not the case for the 5° angle proposed in the report and as used by the author; if the second-order terms are neglected, $\lambda_c = 2{\cdot}255''$.

A similar theory developed by the author treats the half-section of guide as a radial waveguide of infinite height, and the terminating planes of the resonator in the radial guide are assumed to be tangential to the centre line and to the wall of the hexagonal guide (Fig. 2).

It is only required to consider the dominant H-mode in radial guide in which the electric field lines are circular arcs. The transmission-line characteristics for the dominant E-mode have been examined by Marcuvitz[5], and the principle of duality may be applied to obtain results for the H-mode.

If $Z'(r_1)$ is the input impedance of the radial waveguide at a radius $r = r_1$ and $Z'(r_2)$ is the output

Fig. 4. *Crystal holder*



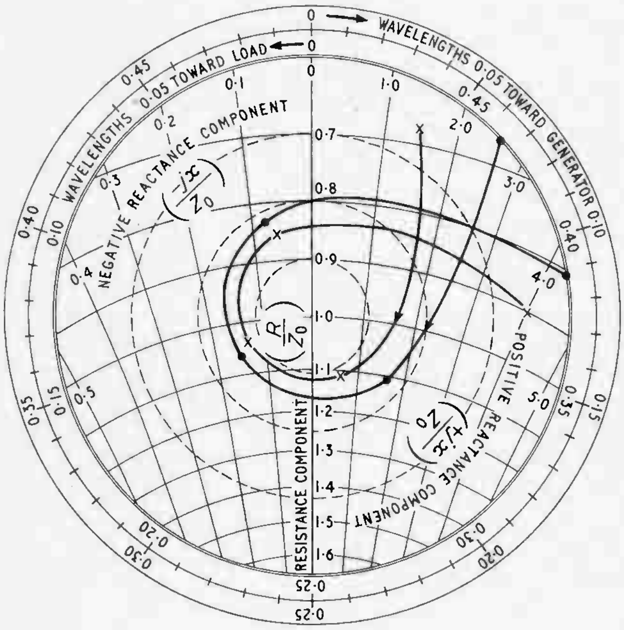


Fig. 5. *Admittance of waveguide crystal holder over a* 10% *band;* • *rectangular waveguide,* × *hexagonal waveguide. The arrows show the direction of increasing frequency*

impedance of the radial waveguide at a radius $r = r_2$ then

$$Z'(r_1) = \frac{j + Z'(r_2)\,.\,\xi\left(\frac{2\pi r_1}{\lambda}, \frac{2\pi r_2}{\lambda}\right) \mathrm{ct}.\left(\frac{2\pi r_1}{\lambda}, \frac{2\pi r_2}{\lambda}\right)}{\mathrm{Ct}\left(\frac{2\pi r_1}{\lambda}, \frac{2\pi r_2}{\lambda}\right) + j\,Z'(r_2)\,.\,\xi\left(\frac{2\pi r_1}{\lambda}, \frac{2\pi r_2}{\lambda}\right)}$$

where ξ, ct and Ct are functions involving the quotient of the differences between products of Bessel functions of the first and second kinds of zero and first orders (ct and Ct are termed radial cotangent functions). The functions are defined in Marcuvitz (ref. 5, p. 33).

We wish $Z'(r_2)$ to be infinite and thus

$$Z'(r_1) = -j\,.\,\mathrm{ct}\left(\frac{2\pi r_1}{\lambda}, \frac{2\pi r_2}{\lambda}\right)$$

Expressing this in its Bessel function form and, since $Z'(r_1)$ is zero, we get

$$J_1\left(\frac{2\pi r_1}{\lambda}\right).\,N_0\left(\frac{2\pi r_2}{\lambda}\right) = N_1\left(\frac{2\pi r_1}{\lambda}\right).\,J_0\left(\frac{2\pi r_2}{\lambda}\right) \qquad (5)$$

TABLE 1

Values of $\frac{2\pi r_2}{\lambda_c}$ giving zeros of J_0 and N_0	Values of $\frac{2\pi r_1}{\lambda_c}$ giving zeros of J_1 and N_1	$\frac{2\pi r_2}{\lambda_c} - \frac{2\pi r_1}{\lambda_c} = \frac{\pi a}{\lambda_c}$	$\frac{r_2}{r_2 - r_1} \times \frac{b}{a\,.\tan\theta}$
3·958	2·197	1·761	2·2476
5·520	3·832	1·688	3·2701
7·086	5·430	1·656	4·2790
8·654	7·016	1·638	5·2833
10·222	8·596	1·626	6·2866
11·792	10·174	1·618	7·2880
13·361	11·749	1·612	8·2885
14·931	13·324	1·607	9·2912

J_0, J_1 are Bessel functions of the first kind; N_0, N_1 Bessel functions of the second kind. This equation now relates λ, the wavelength at cut-off, to the guide dimensions.

A complete solution of this equation is laborious, but point solutions from a table of zeros of the functions J_0, J_1, N_0, N_1 may be obtained as in Table 1.

Comparison of the Cut-off Wavelength Theories

The theories may be compared by substituting the values of $b/a\,.\tan\theta$ from Table 1 in Equs. (3) and (4) in turn, and comparing the resulting values of $\pi a/\lambda_c$ with those derived above. These values are shown in Table 2. Equ. 3 is actually in terms of $b/a\,.\,\theta$, but it may be evaluated using $b/a\,.\tan\theta$; inspection of the theory shows that this form is, in fact, more strictly correct. This last point, however, is of academic interest only, since the distinction affects λ_c by only one part in ten thousand.

TABLE 2

$\frac{b}{a\,.\tan\theta.}$	$\frac{\pi a}{\lambda_c}$, from Equ. (5)	$\frac{\pi a}{\lambda_c}$, from Equ. (3)	$\frac{\pi a}{\lambda_c}$, from Equ. (4)
2·2476	1·761	1·764	1·777
3·2701	1·688	1·690	1·695
4·2790	1·656	1·657	1·660
5·2833	1·638	1·639	1·640
6·2866	1·626	1·627	1·628
7·2880	1·618	1·618	1·619
8·2885	1·612	1·612	1·613
9·2912	1·607	1·607	1·608

For the experimental guide quoted previously $b/(a\,.\tan\theta)$ is 5·1114, in which region the values of $\pi a/\lambda_c$ differ by less than 0·1%; the radial guide theory gives the largest value of λ_c. It is possible that the radial guide expression is the true limit of the variational approach, to which Equ. (4) is only an approximation; it is however a sufficiently accurate approximation for most design purposes.

The Impedance of Hexagonal Waveguide

For the junction of two waveguides of cross-sections S and S' transversely coupled by an aperture A, the ratio of the characteristic admittances has been shown[6] to be

$$\frac{Y'_0}{Y_0} = \frac{\lambda_g}{\lambda'_g}\,.\,\frac{\int\left(\frac{\delta V}{\delta x}\right)^2.\,dS}{\int\left(\frac{\delta V'}{\delta x}\right)^2.\,dS'} \times \frac{\int\left(\frac{\delta V'}{\delta x}\right)^2.\,dA}{\int\left(\frac{\delta V}{\delta x}\right)^2.\,dA}\,.. \qquad (6)$$

where $V = \sin\frac{\pi x}{a}$

and $V' = \sin\frac{\pi x}{a'}$

λ_g and λ'_g are the guide wavelengths for the dominant mode, and a and a' are defined in Fig. 3.

For the particular case of equivalent rectangular and hexagonal waveguide, the guide wavelengths are equal as the guides are designed to have the same cut-off wavelength. It is also required that Y_0 and Y'_0 should be equal.

The condition for equivalent guides thus reduces Equ. (6) to

$$\left[\int \cos^2 \frac{\pi x}{a} \,.\, dS\right]\left[\int \cos^2 \frac{\pi x}{a'} \,.\, dA\right] = \left[\int \cos^2 \frac{\pi x}{a'} \,.\, dS'\right]\left[\int \cos^2 \frac{\pi x}{a} \,.\, dA\right] \quad \ldots \quad \ldots \quad (7)$$

The limits of integration for dS and dS' are clear enough, but dA should strictly be integrated over the rather complex aperture between the guides. An approximate solution may, however, be found by assuming the overlap at the centre to be small, so that x varies from zero to $a'/2$, y from zero to $(b/2 - \theta x)$.

Then, putting these limits in Equ. (7), integrating and using the approximations

$$\sin \frac{\pi a'}{a} \approx \pi\left(1 - \frac{a'}{a}\right)$$

$$\text{and } \cos \frac{\pi a'}{a} \approx -\left\{1 - \frac{\pi^2}{2}\left(1 - \frac{a'}{a}\right)^2\right\}$$

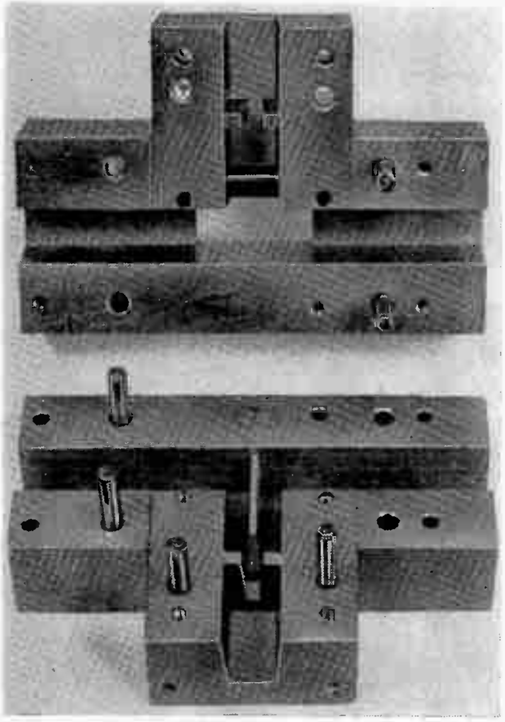
we obtain

$$b = b' + a' \,.\, \theta\left\{\frac{1}{2} - \frac{2}{\pi^2}\right\} \quad \ldots \quad (8)$$

If a further calculation is carried out which endeavours to take into account the small areas of overlap at the centres of the guides, the following expression is obtained:

$$b = b' + a' \,.\, \theta\left\{\frac{1}{2} - \frac{2}{\pi^2}\right\} + \frac{2}{\pi^2} \,.\, \frac{(a'\theta)^2}{b'}\left\{\frac{1}{2} - \frac{2}{\pi^2}\right\}^2 \quad (9)$$

Fig. 6. *Hybrid tee*



Design Equations for Hexagonal Waveguide

From Equ. (3) the condition for equivalence of cut-off wavelengths gives

$$\left(\frac{a}{a'}\right)^2 = \frac{1 - \frac{a\theta}{b}\left\{\frac{1}{2} - \frac{2}{\pi^2}\right\}}{1 - \frac{a\theta}{b}\left\{\frac{1}{2} + \frac{2}{\pi^2}\right\}} \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

For the characteristic impedances also to be equivalent, from Equ. (9)

$$\frac{b}{b'} = 1 + \frac{a'\theta}{b'}\left\{\frac{1}{2} - \frac{2}{\pi^2}\right\} + \frac{2}{\pi^2}\left\{\frac{a'\theta}{b'}\right\}^2\left\{\frac{1}{2} - \frac{2}{\pi^2}\right\}^2 \quad (11)$$

where the quantities a, b, a', b', θ are as defined in Fig. 3.

Equations (10) and (11) may be used to deduce an approximate expression for a/b; viz.:

$$\frac{a}{b} \approx \frac{a'}{b'}\left[1 - \frac{a'\theta}{b'}\left\{\frac{1}{2} - \frac{4}{\pi^2}\right\}\right]$$

If this is then substituted in Equ. (10), it gives

$$\frac{a}{a'} = 1 + \frac{2}{\pi^2}\left\{\frac{a'\theta}{b'}\right\} + \frac{10}{\pi^4}\left\{\frac{a'\theta}{b'}\right\}^2$$

The design equations are therefore

$$\left.\begin{aligned} \frac{a}{a'} &= 1 + \frac{2}{\pi^2}\left\{\frac{a'\theta}{b'}\right\} + \frac{10}{\pi^4}\left\{\frac{a'\theta}{b'}\right\}^2 \\ \frac{b}{b'} &= 1 + \frac{a'\theta}{b'}\left\{\frac{1}{2} - \frac{2}{\pi^2}\right\} + \frac{2}{\pi^2}\left[\frac{a'\theta}{b'}\right]^2\left[\frac{1}{2} - \frac{2}{\pi^2}\right]^2 \end{aligned}\right\} \quad (12)$$

These equations agree with Equs. (45) and (46) of Farmer's Article[6], but are taken to a further order of accuracy. This is necessary when using a 5° taper, especially on reduced height (reduced impedance) waveguides, as is seen in the examples below.

*Dimensions for Equivalents to W.G.*15 *and W.G.*16 *using Equ.* (12)

Equivalent to W.G.15 with 5° taper:

$$\theta = 5^\circ$$

$$\left.\begin{aligned} a' &= 1{\cdot}122'' \\ b' &= 0{\cdot}497'' \end{aligned}\right\} \text{giving} \left\{\begin{aligned} a &= 1{\cdot}172''; \ (1{\cdot}122'' + 0{\cdot}045'' + 0{\cdot}005'') \\ b &= 0{\cdot}526''; \ (0{\cdot}497'' + 0{\cdot}029'' + 0{\cdot}0003'') \end{aligned}\right.$$

An equivalent guide arrived at empirically had $a = 1{\cdot}174''$, $b = 0{\cdot}525''$.

Equivalent reduced height W.G.15 with 5° taper:

$\theta = 5^\circ$
$a' = 1{\cdot}122''$ $b' = 0{\cdot}151''$ giving
$a = 1{\cdot}317''$; $(1{\cdot}122'' + 0{\cdot}147'' + 0{\cdot}048'')$
$b = 0{\cdot}181''$; $(0{\cdot}151'' + 0{\cdot}029'' + 0{\cdot}001'')$

Equivalent to W.G.16 with 5° taper:

$$\theta = 5^\circ$$

$$\left.\begin{aligned} a' &= 0{\cdot}900'' \\ b' &= 0{\cdot}400'' \end{aligned}\right\} \text{giving} \left\{\begin{aligned} a &= 0{\cdot}939'' \\ b &= 0{\cdot}423'' \end{aligned}\right.$$

The theory ignores the small corner radii which are found to be advisable to facilitate manufacture. Such radii, normally less than 3% of the major waveguide dimension, may be neglected in the theory, especially if they are identical in both waveguide cross sections.

Components in Hexagonal Waveguide

To illustrate the practical use of this theory, some components which had already been developed in rectangular waveguide were successfully transferred into hexagonal guide. Some empirical development was necessary to ensure the same performance as the rectangular guide components, since an estimate had to be made in transferring the sizes of irises. The initial estimate utilized the same aperture size between the edge of the iris and the centre line of the waveguide in the two equivalent guides. The validity of the assumption that the susceptances would be similar in both cases was checked experimentally by measuring the susceptances of irises 0·031 inches thick. The error between either of these measured susceptances and the theoretical susceptance for an iris in W.G.15 was less than 4% for a normalized susceptance of 0·2; the error increased slightly for smaller irises and decreased for larger irises. If a considerable amount of work using hexagonal guides is envisaged, the theory developed above might be extended to cover iris susceptances by considering the slight variation of field caused by the hexagonal guide.

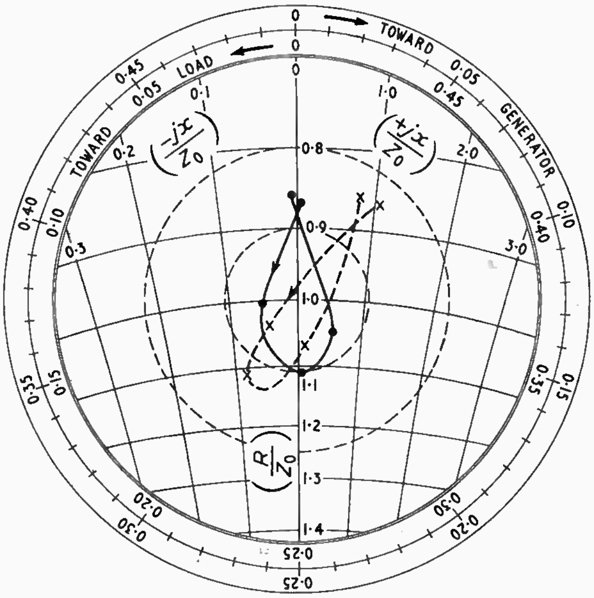
E-plane Mitred Corner

A mitred corner having a v.s.w.r. better than 0·95 over a 10% bandwidth was designed in hexagonal guide by direct transference of dimensions from rectangular guide via the theory.

Crystal Holder

Fig. 4 shows the two halves which when placed together form one complete crystal holder. This holder consists of a low-impedance waveguide section, in which a transition between waveguide and coaxial line is situated, and a transformer matching the low-impedance section to the hexagonal waveguide equivalent to W.G.15. Both the low-impedance section and the transformer are in hexagonal waveguide; Equ. (12) is still relevant for these sections, the smaller section being worked out in the reduced height example above. The crystal is a standard CV2154 and the i.f. output has a simple two-section filter. The comparison of performance between the W.G.15 and equivalent hexagonal waveguide components using the same mean crystal is shown in Fig. 5.

Fig. 7. *Admittance of the series arm of waveguide hybrid tee over a* 10% *band;* • *rectangular waveguide,* × *hexagonal waveguide. The arrows show the direction of increasing frequency*



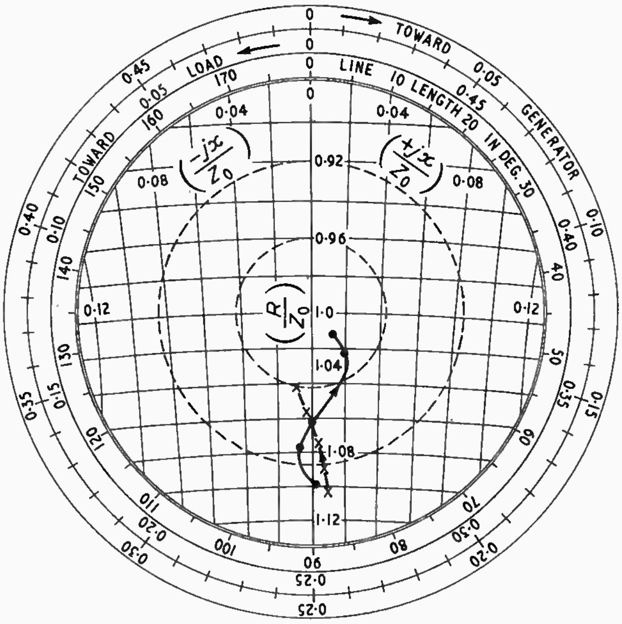


Fig. 8. *Admittance of shunt arm of waveguide hybrid tee over a* 10% *band;* • *rectangular waveguide,* × *hexagonal waveguide. The arrows show the direction of increasing frequency*

Hybrid Tee

The hybrid tees for the two waveguides were not completely equivalent since the experimental unit, shown in Fig. 6, was made to simulate a possible die-casting. Both inductive and resonant irises were therefore tapered, but the post of the W.G.15 tee was replaced by the web, as shown in Fig. 6. In addition, the shunt arm was made to standard W.G.15 dimensions since it could be broached from a casting; to have carried the 5° taper along the length of the shunt arm would have reduced the waveguide cross-section too much. Figs. 7 and 8 show the performances of the two equivalent hybrid tees.

Matched Terminations

A very suitable matched termination for hexagonal waveguide may be made as detailed in British patent applications 11394/55 and 9456/56. It consists of a tapered or stepped cone placed in the waveguide with its axis along that of the waveguide and its apex towards the incident power. Such a cone may have a circular cross-section and may be made self-locating by causing the circumference of the base to inscribe the four walls of the major waveguide dimension. With a taper length of $1\frac{1}{2}$ wavelengths, a v.s.w.r. of better than 0·99 has been obtained over a 10% band.

Conclusions

The close agreement between the practical performance of a hexagonal waveguide component and its rectangular waveguide equivalent from which it was designed with the aid of the theory shows that no difficulty should be experienced in transferring a design in rectangular waveguide into one suitable for die-casting. The laboratory development time has been found to be small even for quite complex components.

For reduced impedance waveguide, the expressions in Equ. (12) do not converge very rapidly, whereas the radial transmission theory is still valid and can be made to give the cut-off wavelength to a greater accuracy.

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REFERENCES

[1] C. G. Montgomery, R. H. Dicke and E. M. Purcell, "Principles of Microwave Circuits", M.I.T. Radiation Laboratory Series, Vol. 8, pp. 44-45. McGraw-Hill.

[2] J. Brown, University College, London. Unpublished communication to the author.

[3] Unpublished Ministry of Supply Report.

[4] S. A. Schelkunoff, "Electromagnetic Waves", 1944, Sect. 7.27. Van Nostrand.

[5] N. Marcuvitz, "Waveguide Handbook", M.I.T. Radiation Laboratory Series, Vol. 10, 1951, pp. 29-47.

[6] E. D. Farmer, "Junction Admittance between Waveguides of Arbitrary Cross-Sections", *Proc. Instn elect. Engrs,* Part C, March 1956, Vol. 103, No. 3, pp. 145-152.

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By Quantum

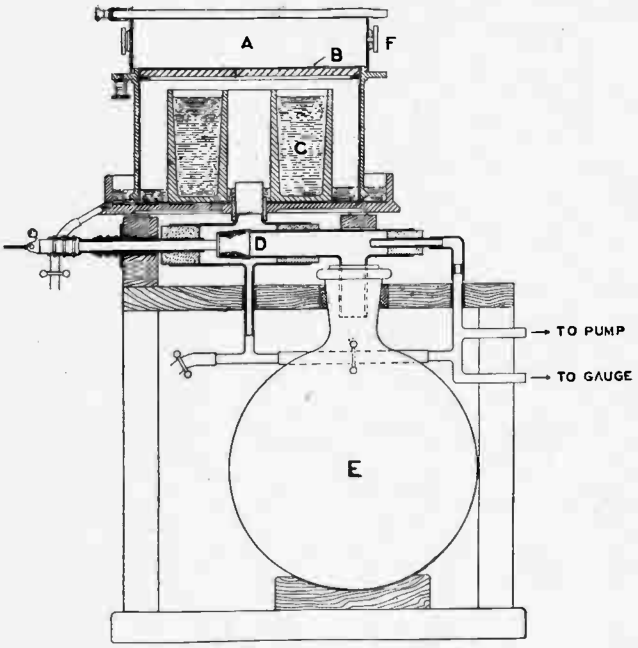
THE CLOUD CHAMBER

In the October issue of the *Journal of Scientific Instruments*, Dr. R. A. Smith of R.R.E., Malvern, contributes a stimulating article on "Physics and the New Electronics". His general theme is the very close intertwining of fundamental physics and electronics nowadays, and he cites as examples of this the maser, developments in semi-conductor and solid-state physics generally and, of course, the Malvern work on photoconductive cells which I mentioned briefly last month. His conclusion is that the electronic engineer of the future will have to be a pretty accomplished physicist as well. I think one could go a little further than that, and say that a good many electronic engineers at the present time are already applying their talents to fundamental physics in a way that the ordinary kind of physicist can only envy and admire. The most recent example of this is the conversion of the Wilson cloud chamber into a resonant cavity, in which microwave timing-marks are imposed on the familiar cloud-track of an ionizing particle. The work, as it has progressed so far, is described by Dr. D. Gabor and B. Hampson, of Imperial College, in *Nature* for 12th October 1957. This achievement, and the challenge of the problems encountered at its present stage, has aroused a good deal of interest; and I thought that it might help you to appreciate the value of this development if I traced the history of the cloud chamber up to the present time.

The Theory of the Cloud Chamber

Water, or any other liquid, in a confined space evaporates until the pressure of the vapour above it reaches the maximum, or saturation, value for the particular temperature. This vapour pressure increases with the temperature. If the temperature of the enclosure is lowered, the necessary vapour pressure is also lowered, and a new equilibrium is reached by condensation of some of the vapour. But it does not follow that equilibrium is reached at once, and supersaturated vapour, at the original pressure (or a little less, depending on the method of cooling), *may* persist—an unstable state of affairs which adjusts itself only when something happens to start or assist condensation, or the degree of supersaturation is relatively great. As long ago as 1895, C. T. R. Wilson studied the effect of cooling air saturated with water-vapour by sudden adiabatic expansion. The volume change from V_1 to V_2 reduces the temperature from T_1°K to T_2°K, the usual adiabatic equation $T_1 V_1^{(\gamma-1)} = T_2 V_2^{(\gamma-1)}$ applying, where γ is the ratio of the principal specific heats of air. In dust-free air, no condensation was observed for values of V_2/V_1 less than 1·25, when some was detectable; complete condensation was obtained for $V_2/V_1 = 1{\cdot}38$. Later, in 1899, using X-rays to ionize the air in the expansion chamber, and plates with an electric field maintained between them to separate out the ions, he showed that condensation occurred on negative ions as nuclei for an expansion ratio of 1·25; on positive ions as well at 1·31; and without the need for any ions at all at 1·38. In Table 1 (assuming T_1 to be 300°K, when the vapour pressure p_1 is 37 millibars) the temperature T_2, the vapour pressure at this temperature p_2, and the degree of supersaturation α (which is p_1/p_2 divided by the expansion ratio and corrected for the temperature change) are given.

The first point to take up is why supersaturation



(*Courtesy Cambridge Instrument Co.*)

Fig. 1. *The Wilson Cloud Chamber of* 1911

A, expansion chamber; B, piston, covered with black gelatine, shown at the bottom of its traverse; at C and around is water to ensure saturation. The piston was brought down quickly by opening communication through D with the partly evacuated flask E. At F is a thin window for the source; the terminals for the clearing field voltage are to the left of A

happens at all, and why it should break down at $\alpha = 8 \cdot 0$. The usual simple explanation invokes surface tension, and instead of showing why small drops are not formed at once, it says why they would tend to evaporate into supersaturated vapour if we had them to begin with. A spherical drop of radius r cm, and surface tension S dynes/cm experiences an inwardly-directed pressure $2S/r$ dynes/sq. cm, which tends to reduce its surface and so favours evaporation in circumstances when it might be expected to be stable or even grow. As the effect is proportional to $1/r$, very small drops tend to evaporate into slightly supersaturated vapour; but if the supersaturation is great enough they can grow. The value of α which would permit a drop to grow, obtainable by Kelvin's thermo-dynamical argument (see, for example, Newman & Searle's "General Properties of Matter"), is given by

$$\log_e \alpha = \frac{2\,S\,M}{\rho\,R\,T_r},$$

where M is the molecular weight and ρ the density. For water, taking S as 73 dynes/cm at 300°K, and ρ as 1 gm/c.c., we have for

$$\begin{array}{ll} \alpha = 4 \cdot 4 & r = 7 \times 10^{-8}\text{ cm.} \\ \alpha = 5 \cdot 9 & r = 6 \times 10^{-8}\text{ cm.} \\ \alpha = 8 \cdot 0 & r = 5 \times 10^{-8}\text{ cm.} \end{array}$$

TABLE I

Expansion ratio V_2/V_1	Temperature T_2	Vapour pressure p_2	Degree of super-saturation α
1·25	274°K	6·5 mb.	4·4
1·31	269	4·5	5·9
1·38	264	3·1	8·0

Now, the *diameter* of a water molecule is of the order of 4×10^{-8} cm and, although it is a gross over-simplification to think of spheres or even surfaces on this scale, the explanation has a certain consistency about it. The smallest incipient drop formed by two or more water molecules could just about sustain itself at $\alpha = 8{\cdot}0$ as found by Wilson; and once it had begun to grow by collecting other molecules it would be well away.

The second point, and the really important one, is the effect of electric charge in promoting condensation at lower values of α. A charged ion, with q.e.s.u., attaching itself to a droplet of radius r cm has its charge effectively distributed over a surface of area $4\pi r^2$ sq. cm, and the outwardly directed electrostatic pressure (the usual $2\pi\sigma^2/k$ in c.g.s.) opposes the inwardly-directed $2S/r$ of the surface tension, and reduces it to $(2S/r - q^2/8\pi r^4)$. Taking q as $4 \cdot 8 \times 10^{-10}$ e.s.u., the value of r for which this is zero works out to $3 \cdot 8 \times 10^{-8}$ cm, but this is smaller than the smallest incipient drop of the last paragraph. A better way of looking at this calculation is to see what happens for a drop of radius 5×10^{-8} cm. Here, it turns out that $2S/r$ is reduced by rather more than half, so that if uncharged water molecules can just form droplets of this size at $\alpha = 8 \cdot 0$, then the presence of a single electronic charge would readily cause condensation at $\alpha = 4 \cdot 4$.

The theory outlined above shows that, once droplets have been formed, they will be able to grow of their own accord, for as r increases by the collection of other water molecules, the effect of $2S/r$ diminishes progressively. This means that, while the ionizing particles which produce the charges acting as nuclei for the initial droplets must traverse the chamber very shortly after the expansion, the instant at which the tracks are observed or photographed must also in its turn be very soon after they are produced, for large-scale condensation could follow quickly. But, in any event, the 'sensitive time' is short, for the chamber simply warms up again after a few milliseconds, frustrating further condensation. The general procedure in all water-using cloud chambers is to expand so that V_2/V_1 lies somewhere between 1·25 and 1·38; allow the ionizing particles to cross the chamber; illuminate and photograph just afterwards, catching the line-cloud formed in the track of a particle at the stage when the droplets are at a suitable size; and then to clear the chamber of ions ready for the next exposure by applying an electric field.

In spite of the fact that the concept S has been used for a scale at which we cannot nearly imagine a continuous surface, this general argument is acceptable; for S is the easily measurable effect of *molecular attraction.* A further treatment is given in the first two chapters of B. J. Mason's *The Physics of Clouds* (Oxford University Press, 1957).

The Wilson Chamber

By 1911, the Wilson chamber had been developed to the instrument shown in Fig. 1. Some ten years later, when large numbers of photographs had to be taken in the search for infrequent collision events, Shimizu devised a mechanism for arranging the whole

(Courtesy Cambridge Instrument Co.)

Fig. 2. *Curvature of α-particle tracks in a very strong magnetic field, applied perpendicular to the plane of the picture and directed upwards*

cycle from expansion to clearance upwards of 200 times a minute. Then Wilson fitted a rubber diaphragm for the expansion instead of the vertically-dropping piston, which meant that the chamber could be used in any position, to deal with more or less vertically-arriving cosmic-ray particles. The final mechanical perfection came with the counter-controlled chamber for cosmic-ray work; counters on each side of the chamber, in a coincidence circuit, were arranged to trigger off the cycle only when a particle passed through it in the line through the two counters.

Every book on atomic physics contains numerous cloud-chamber pictures, which are usually illustrations of events such as, for example, the collision of an α-particle with a nitrogen nucleus, the disintegration of a lithium nucleus by a high-energy proton, or some exciting cosmic-ray incident. The principal value of such a picture is that the event itself is put very strikingly on record; but the cloud-track picture also gives a good deal of quantitative information.

First, the kind of ionizing radiation—whether α-particle, proton, meson of one kind or another, electron, or X- or γ-ray photon, can be identified by the course of the track and the density of ionization along it. The recoil-tracks of struck nuclei, and the products of a disintegration, can also—partly from their directions, partly from the droplet-density—be recognized. Even neutrons, which are not ionizing particles, can be detected at second-hand from the tracks of the products of their collisions with nuclei in the chamber.

Secondly, the energy of an ionizing particle is deducible from its range, if this ends in the chamber; Geiger's formula for α-particles states that the range is proportional to $(\text{energy})^{3/2}$. Again, cosmic-ray particles which actuate counters above and below the chamber can be timed in their flight across it.

Thirdly, if m is the mass, v the velocity, and e the charge of the particle (e may be one electronic charge, of either sign, or can here stand for two or even more) then a magnetic field of flux-density B applied across the chamber at right angles to the plane of the picture bends the track into an arc of radius r given by $B e v = m v^2/r$ in consistent units (Fig. 2). Thus, the momentum $mv = B e r$ can be determined and, furthermore, the *sign* of e is at once evident from the direction of the curvature. The historic example of this is the discovery of the positron by C. D. Anderson in 1932. He photographed what was certainly an electron-track, with the direction of travel identified; but this was curved in the same sense as those of the positively-charged α-particles of Fig. 2. An ordinary negative electron would have swerved the other way.

To sum up the quantitative possibilities so far, then, the ionizing particle can be identified; its momentum can be determined; its energy can be estimated; and if it happens to go right through the chamber it can be timed across it. But *if it happens to stop in the chamber, then there is no direct means of timing it*, though of course v can be deduced from the momentum.

Gabor and Hampton's Development

It is often stated in the books (though without much explanation of either instrument) that the Geiger counter was a development of the Wilson chamber; if this really means anything it is an analogy, for all they have in common is being able to deal with single particles if required. In one case, in a critically adjusted electric field, the resulting ions precipitate an electron avalanche while, in the other, they initiate water droplets and there is no breeding of ions. I said earlier that Gabor and Hampton had converted the cloud

(Courtesy Dr. D. Gabor, F.R.S., and "Nature".)

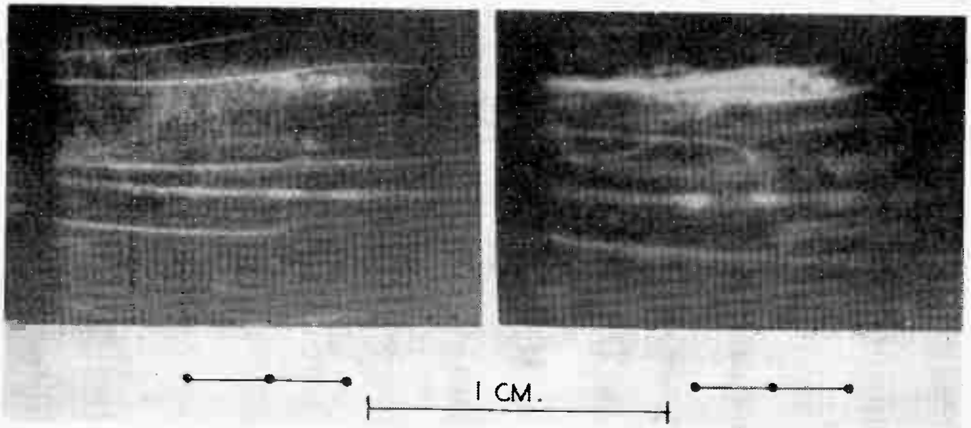


Fig. 3. *Cloud-tracks obtained in the cavity cloud-chamber. The thickened portions occur at time-intervals of about* 10^{-10} *sec*

chamber into a microwave cavity; but there is a good deal of Geiger-countering involved as well in principle. For, at intervals along the path of the original particle, an electron avalanche is *started*; but it is not allowed to develop very far—just far enough to breed sufficient fresh ions to give a notable thickening of the cloud-track in these places. With the chamber operating as a resonant cavity at 3,000 Mc/s, these intervals succeed one another every 10^{-10} second. The track thickenings thus give the first available *direct* means of timing such a particle in flight (Fig. 3.).

The chief difficulty so far encountered by Gabor and Hampton has been in getting sufficient power. First, the peak voltage must be very close to the breakdown voltage (which would give a thorough "counter" avalanche) for the miniature avalanches to start at all. For air, this is 28 kV/cm, which requires a peak energy of 4×10^{-5} joule per c.c. of the chamber volume. If Q is 1,000, at 3,000 Mc/s, since this energy has to be supplied ω/Q times per second, the power needed works out to 750 watts/c.c. This is high, but even then air is not a suitable gas; the ideal substance is a gas with so high an electron affinity that the miniature avalanche is cleared up very quickly once the field has passed the peak. Freon would be suitable on these grounds, but the breakdown field is 90 kV/cm, and it would require 10 kW/c.c. As the highest power available was 2·2 kW, from a G.E.C. experimental magnetron VX 3043 which was spectacularly over-run, they had to settle for hydrogen, simply because its breakdown field of 15 kV/cm brought matters within this power range. A further complication was that, since the field must approach but not exceed the breakdown value, a slight ripple in the magnetron power supply sufficed to overstep the limit and give a complete breakdown in a high proportion of the exposures. Nevertheless, successful photographs were obtained with α-particles from thorium 288, and the velocities measured were in agreement with the accepted values obtained by less direct methods.

High-Pressure Cloud Chambers

To return to an earlier problem—how can high-energy particles which pass through an ordinary chamber be made to end their travels inside a chamber so that their fate can be examined? The stopping power of any medium for such particles depends in general on the number of atoms presented per centimetre of its path (being proportional to the density for a given gas) and on the atomic weight A (proportional to $A^{1/2}$, as was shown by Sir William Bragg for α-particles). Argon ($A = 40$) is about half as effective again as air, and modern chambers use this gas at pressures of the order of 75 atmospheres, with alcohol instead of water which allows of a smaller expansion ratio. An 8-inch diameter chamber of this kind, being operated at a height of 2,000 metres in the Dolomites by a joint group from University College, London, and the University of Edinburgh, was described in *Nature*, 12th March 1955. This would arrest 44 MeV protons, 18 MeV μ-mesons, and 20 MeV π-mesons.

The Bubble Chamber

Finally, the whole cloud-chamber process can be operated with the phases reversed. Surface tension is a *surface* effect, tending to reduce surface area whether it is the convex surface surrounding a drop of liquid in air, or the concave surface bounding a bubble of vapour in a liquid. All that has been said about surface tension favouring the evaporation of a drop, or discouraging its formation until a high degree of supersaturation is reached, applies to the discouraging of the formation of vapour bubbles within a liquid in the ordinary process of boiling. Normally, boiling occurs when the vapour pressure within the bubbles can just withstand the external pressure, provided nuclei of some kind (dissolved air being released as little bubbles in the case of water) are available to start things. If there are no nuclei, the effect of $2S/r$ in a tiny incipient bubble is to require a vapour pressure greater than the outside pressure, so that the liquid has to be superheated above the normal boiling-point before anything happens (which may be quite violent when it does). Charged ions, with the $2\pi\sigma^2/k$ effect, counteract $2S/r$ as before, and act as nuclei for the *boiling* of a superheated liquid; and energetic particles ionize the molecules of the liquid that they encounter, much as they behave in a gas. So, if the right moment for observation between the passage of an ionizing particle and large-scale boiling is chosen, the track of the particle is shown as a trail of vapour bubbles in the liquid. Liquid hydrogen, pentane, methyl alcohol, and numerous other liquids have been used in bubble chambers, first described by D. A. Glaser in 1952. The procedure is to heat the liquid above its normal boiling-point, and maintain it there under the necessary pressure; reduce the external pressure, so that it is now superheated; expose to the ionizing particles, and quickly illuminate and photograph in the short interval before things get out of hand. The chamber is reset by applying the external pressure again. The great advantage of the bubble-chamber is its stopping power for high-energy particles, and it is one of the instruments developed to cope with the output of the great accelerating machines—home-made mesons and so on. It has already become a standard technique in this field—which seems so far from the fringe of our own; and yet perhaps not really so remote when you reflect that timing the flight of an α-particle is a feat of microwave engineering, which may be very widely applied when the necessary kilowatts are available.

AWARD OF FARADAY MEDAL

The Council of the Institution of Electrical Engineers have made the thirty-sixth award of the Faraday Medal to Sir Gordon Radley, K.C.B., C.B.E., Ph.D.(Eng.), the immediate past-president of the Institution, for his outstanding contributions in the field of international communications and particularly in the development of long-distance deep-sea telephone cables and their repeaters.

PHYSICAL PROBLEMS OF COLOUR TELEVISION

The journals *Optica Acta* and *Acta Electronica* have undertaken the joint publication of the full proceedings (invited lectures and communications, mostly in English) of the International Symposium on the Physical Problems of Colour Television, held in Paris last July. A limited number of the copies of the volume (pp. 400, with over 450 illustrations) will be available to non-subscribers to the journals. Advance subscriptions (£4 post paid) to *Optica Acta*, 3 boulevard Pasteur, Paris 15e, or *Acta Electronica*, 23 rue de Retrait, Paris XX°, France, before 1st January.

Waveform Testing Methods for Television Links

By A. R. A. Rendall, O.B.E., Ph.D., B.Sc., M.I.E.E.*

SUMMARY. *The subjective effects of phase and frequency distortion in television links are not readily discernible from steady-state measurements of transmission characteristics. Since the fundamental requirement is the preservation of waveform, a system of testing links by means of three standard waveforms has been evolved. Acceptance limits for received waveforms have been fixed by relating the waveform distortions to subjective picture quality, and a rating factor established.*

It is well known that the conditions for distortionless transmission of pulse signals are that the loss should be uniform with frequency and the phase angle proportional to frequency. The two quantities loss and phase angle can be measured with reasonable ease and accuracy and also, when links are connected in tandem, their respective losses and phase displacement angles can be directly added. It is very difficult, however, to define satisfactory working limits for television transmission in terms of these two separate quantities, as the subjective effect of distortion cannot be identified with either of them separately. For want of a better specification, working limits of loss and phase distortion have been used in the past in designing overall television chains, but it has been realized that transmission characteristics meeting these limits might be either unnecessarily stringent or unsatisfactory. The fundamental requirement for good-quality transmission is preservation of waveform. The time of rise of the edges and overshoots can be directly associated with resolution and ringing, although there are other features of waveform distortion that are more difficult to associate with subjective appreciation. It was found convenient to divide the distortions experienced into three categories depending on the time magnitudes over which they operated: those of time duration comparable with field time (20 milliseconds), those of time duration comparable with line time (100 microseconds), and those occurring at sudden transitions where the video bandwidth determines their character. Stated in the older, and perhaps more familiar terms, the three categories are for distortions associated with field, line and upper frequency response. For the first two categories square waves with repetition rates at field and line frequency respectively are the most suitable test pulses. For this purpose the distortion of the top of the bar is studied, as this reveals the distortion in the frequency region near the repetition frequency.

The most suitable waveform to explore the distortion of short-term transients has been the subject of much discussion, and agreement cannot yet be recorded. The requirements are that the test signal should be reasonably easy to generate in a repeatable form, and that its frequency spectrum should be restricted as far as practicable to the 3-Mc/s band. The practical transmission link often has a well-defined upper-frequency limit, as the aim of equalization is to make each link approximate to an ideal low-pass filter, having zero attenuation to a certain critical frequency f_c and thereafter the response to fall rapidly. The object of adopting this procedure is so that links can be operated in tandem with no summation of loss up to the nominal cut-off frequency f_c. In this country the value adopted for f_c is 3 Mc/s and the majority of the links have a sharp cut-off above this frequency. If the test pulse contains considerable energy outside the accepted limits of the frequency spectrum, then much of the distortion of the received pulse is irrelevant from the point of view of judging the performance of the practical, finite link. The sine-squared pulse has advantages, therefore, because the amplitude–frequency spectrum of such a pulse is 6 dB down at f_c if the half-amplitude duration (T) is $1/2f_c$, and reaches a negligible value at f_c if the half-amplitude duration is $2T$.

The linear performance of a link can therefore be judged by three pulse signals, a square wave with a 50-c/s repetition rate, a square wave with a 10,000-c/s repetition rate, and a sine-squared pulse of half-amplitude duration of either 1/6 or 1/3 microsecond. For convenience, the 10,000-c/s square wave and the sine-squared pulse were combined into one signal. The next considerable step was to relate the distortions exhibited by such test pulses to subjective picture distortion and to establish limits. Such a programme was undertaken and it finally resulted in the expression of the distortions in the three regions in terms of a rating factor K. K is a fraction which expresses the departure from normality of a pulse as a result of distortion. It may be a change in amplitude or width of the test pulse or the addition of a ripple. The percentage departure is not itself a measurement of the K-factor as the factor is based on the subjective depreciation of picture quality as a result of the

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*Designs Department, *British Broadcasting Corporation.*

distortion. The maximum overall permissible distortion for a good quality television chain is $K = 0{\cdot}05$. For an individual link or unit of equipment the rating factor would be much smaller, less than 0·01. In long transmission chains the individual rating factors of the links tend to add as the square root of the sum of the squares. If the individual links exhibited systematic errors then the K-factors would tend to add algebraically. This manner of expressing the performance of links is described by Dr. N. W. Lewis[1] and he shows that the time has come to express performance in terms of time rather than of frequency. The technique has progressed to the point that it has been recognised by the International Radio Consultative Committee (C.C.I.R.) and the International Telegraph and Telephone Consultative Committee (C.C.I.T.) as the appropriate method of testing links on the 405-line system. In addition to the linear distortion described above, the waveform may be distorted in a non-linear manner; that is, that the amplitude of the received signal is not proportional to the amplitude of the transmitted signal. Three test signals have therefore been agreed, the first two for measuring linear distortion and the third for measuring non-linear distortion. The signals are shown in Fig. 1.

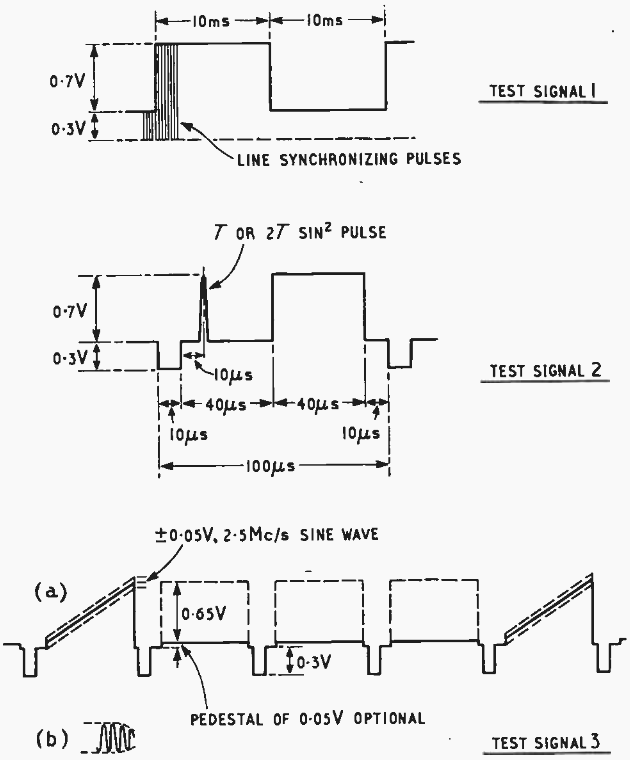


Fig. 1. *The three standard test signals*

Signal 1 is a 50-c/s square wave superimposed on synchronizing signals. Thus, for a period of 10 milliseconds there are only synchronizing pulses, and a few of these are indicated, and for the other 10 milliseconds of the cycle the signal is full white for the whole of the picture period of each line. The normal synchronizing pulses are retained. Distortions at frequencies near field frequency will show up as distortion on the white portion of the received square waveform when it is displayed on an oscilloscope operating with a time-base at field frequency. Shorter time (or higher frequency) distortions will show as a deformation near the black-to-white transitions. If a period of time is neglected on either side of these transitions, consideration of these shorter time distortions can for the time being be disregarded. In Fig. 2 (a) upper and lower limit lines are shown for the white portion of the square wave for the times of interest. The 250-μs interval adjacent to the transition is disregarded.

The square wave of Fig. 2 (a) corresponds exactly to that of test signal 1, but the outline of the square wave only is shown. The limit lines can be drawn on an oscilloscope mask, which also provides indicators for locating the display, and it is immediately apparent whether the link conforms to the required limits. The limits are expressed in terms of the rating factor K.

Signal 2 combines the sin^2 pulse and a 40-μs pulse, both repeated at line speed. The time of rise of the bar has been fixed at 0·33 μs so that the normal limitation of bandwidth of the links to 3 Mc/s will not introduce confusing overshoots. The distortion of the white portion of the bar will reveal, among other defects, distortions of a duration from 1 to 10 μs which are particularly important in television transmission. Again the performance can be defined by two limit lines as shown in Fig. 2 (b). Periods of 1 μs before and after the transitions from black to white are not considered so that the signal has time to settle down after the transition has occurred. It will be noted that more stringent requirements are applied to signal 2 compared with signal 1 as the spacing of the limit lines in Figs. 2 (a) and 2 (b) indicate.

The distortion associated with sudden transitions (or high-frequency distortion) is indicated by deformation of the sin^2 pulse of signal 2. When the $2T$ pulse is used the height of the pulse relative to the bar may be modified, the half-amplitude width of the pulse may be changed, and ripples and irregularities may be introduced on either side of the pulse. Limits for these quantities are defined by the enclosure of Fig. 2 (c). The display of the received sin^2 pulse on the oscilloscope is expanded to conform to certain markers and the performance of the link can be immediately observed. For more precise measurements the sin^2 pulse width is T. The higher frequency components of this pulse are greater than for the $2T$ pulse, and extend out beyond the limiting frequency f_c. Thus the T pulse is more sensitive to high-frequency distortion than the $2T$ pulse but, as it contains irrelevant information, the shape of the received waveform requires a more complex procedure for interpretation than that for the $2T$ pulse. Once a received waveform has been established for the T pulse it is useful for comparison during subsequent routine tests.

The third test signal shown in Fig. 1 is to check the linearity of the link. The picture period of every fourth line is occupied by a saw-tooth with a high-frequency oscillation (2·5 Mc/s) superimposed. The intervening line periods may be occupied by a signal representing either black or full white. The variation of amplitude of the superimposed oscillation along the excursion of the saw-tooth is a measure of non-linearity. The high-frequency oscillation is separated from the rest of the information by a high-pass filter and may be displayed on an oscilloscope with a time-base running at line speed. A display shown at (b) of test signal No. 3 is then obtained, and the change of amplitude of the envelope measures the variation in gain at 2·5 Mc/s with variation in amplitude of the picture signal from black to white. Although this method gives useful information it is agreed that it is not an exhaustive test as regards the linearity of the picture part of the signal. There are some effects which occur relatively slowly, for example, the inability of a power supply unit to respond immediately to a demand for more power is not depicted by this test. More work has to be done before a satisfactory all-embracing test is found.

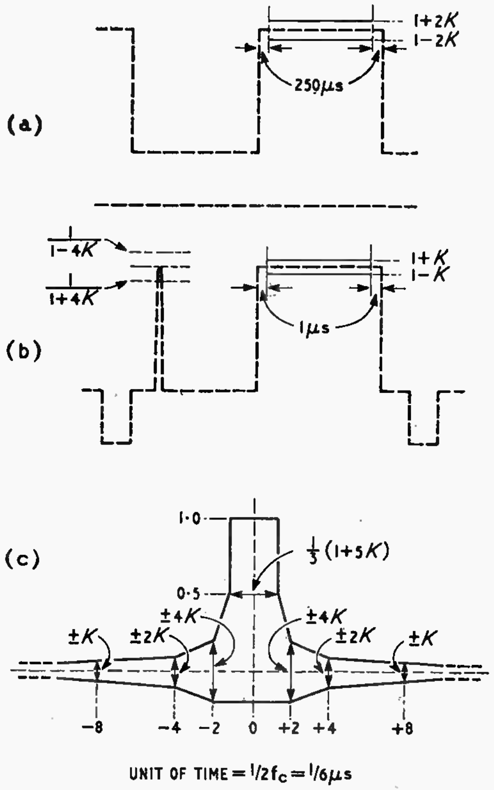


Fig. 2. *Received signals showing acceptance limits*

The linearity, as it affects the synchronizing pulses, is indicated by the change in the amplitude of these pulses as the intervening line signals are changed from black to white. An observation on the shape of the saw-tooth for these two conditions also gives valuable information regarding non-linear distortion affecting the picture.

The tests described were devised for setting up and maintaining long-distance television links, but the procedure, particularly the pulse-and-bar signal No. 2, is an excellent signal for checking distortion in all types of vision apparatus, from amplifiers to high-power transmitters. The method introduces a new concept of waveform correction to replace the old steady-state equalization. The correction of waveform is so much more powerful than the older method because it directly demonstrates what is happening to the quantity of interest—the waveform. A striking example of this is a relatively short video tie line, say some 500 ft. long. It is normal and convenient to terminate this at each end by a constant resistance, usually 75 ohms. At the lower frequencies, owing to the departure of the characteristic impedance of the cable from a pure resistance, reflections occur and the transfer characteristic is very complex. The waveform correction method enables the necessary and sufficient correction to be made directly and easily.

It is expected that this concept of waveform correction will come more and more into use as its essential simplicity is appreciated. It will mean new test apparatus, but will give a better appreciation of what is required for good television transmission.

REFERENCE

[1] N. W. Lewis, "Waveform Responses of Television Links", *Proc. Instn Elect. Engrs.*, Part III, Volume 101, No. 72, July 1954.

MEETINGS

I.E.E.

9*th December*. Discussion on "Where should Research end and Development Start? ", to be opened by K. J. R. Wilkinson, D.Sc.

11*th December*. "A Flying-Spot Film Scanner for Colour Television", by H. E. Holman, G. C. Newton and S. F. Quinn.

12*th December*. "Electrical Control of Stage and Television Lighting", by F. Bentham.

13*th December*. "Basic Experiments on Servo Mechanisms", discussion to be opened at 6 o'clock by W. Chellingsworth, B.Sc.(Eng.).

16*th December*. "Electronics and Automation—Electronics in the Textile Industry", talk by K. J. Butler.

17*th December*. "Recent Uses of Ultrasonics in Investigating the Characteristics of Materials", by J. Lamb, Ph.D., M.Sc.

These meetings will be held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, and will commence at 5.30, *except where otherwise stated.*

The British Computer Society

16*th December*. "Parallel Programming: A Study of a New Technique in Digital Computer Programming ", by Dr. S. Gill, to be held at 6.15 at Northampton College of Advanced Technology, London, E.C.1.

Brit. I.R.E.

18*th December*. "Recent Developments in Electronic Instrument Design", by E. Garthwaite, M.B.E., and A. G. Wray, M.A., to be held at 6.30 at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

The Physical Society

11*th December*. Reports on "Meeting on Colour Television, Paris 1957", by L. C. Jesty; "Symposium on Visual Problems of Colour, Teddington 1957", by Dr. W. S. Stiles; and "C.I.E. Working Party on Colorimetry, Teddington 1957", by Prof. W. D. Wright, to be held in the Physics Department, Imperial College, Imperial Institute Road, London, S.W.7, at 3.30.

The Institute of Physics

10*th December*. "Infra-Red and Microwave Modulators using Free Carriers in Germanium", by Dr. A. F. Gibson, at 5.30.

11*th December*. "Irregularities and Movements in the Ionosphere", by Dr. B. H. Briggs, at 6 o'clock.

These meetings will be held at the Institute of Physics, 47 *Belgrave Square, London, S.W.*1.

The Television Society

13*th December*. "Dressing Television: Cabinet Design", by L. J. Griffen, to be held at 7 o'clock at the Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.

The Society of Instrument Technology

11*th December*. "Automatic Profiling Systems for Machine Tools", by R. Lawson, B.Sc., to be held at 7 o'clock at Manson House, Portland Place, London, W.1.

Computation of Crystal Admittance

A COMPARISON OF MEASURED AND THEORETICAL CHARACTERISTICS

By W. J. Lucas, M.Sc., A.R.C.S.* and P. B. Barber, B.Sc., A.R.C.S.*

SUMMARY. *The paper summarizes the results of a digital-computer programme designed to calculate the admittance, relative to* 1/68 *mho, of a coaxial crystal with the same dimensions as the CV*2226 *for various values of the video resistance R, spreading resistance r and barrier capacitance C over a frequency range* 2,000–18,000 *Mc/s. The equivalent circuit used in the calculation is discussed. From all the available measurements made on CV*2226 *crystals the variation with frequency of the admittance of an 'average crystal' was obtained. It is shown that the computed curve corresponding to $r = 30$ ohms, $C = 0{\cdot}15$ pF and $R = 3{,}000$ ohms reproduces the 'average curve' extremely well. Further, it is shown that the spread in the measured admittance of a batch of crystals at a given frequency can be accounted for by varying r and C in the manner these two parameters are expected to vary in an actual crystal.*

The problem of calculating the admittance of a coaxial type crystal from an equivalent circuit is by no means new; such calculations were made at the G.E.C. Laboratories in 1950†. However, when only a desk calculating machine is available, the amount of work involved makes it impracticable to extend the calculation over a wide range of frequencies and a large number of values of the video resistance R, spreading resistance r and barrier capacitance C. The advent of the digital computer, which is particularly suited to handling problems of a repetitive nature involving systematic changes in the values of one or more parameters, has overcome this difficulty. A digital computer programme was prepared to calculate the admittance of the CV2226 type crystal at regular intervals in the frequency range 2,000–18,000 Mc/s for the following values of the parameter R, r and C:—

R: 3000 (1000) 7000 Ω.
r: 10 (10) 40 Ω.
C: 0·075 (0·025) 0·175 pF.

The purpose of this paper is to summarize the main results of this programme and to assess how well the assumed equivalent circuit describes the measured admittance of the CV2226 crystals.

Equivalent Circuit

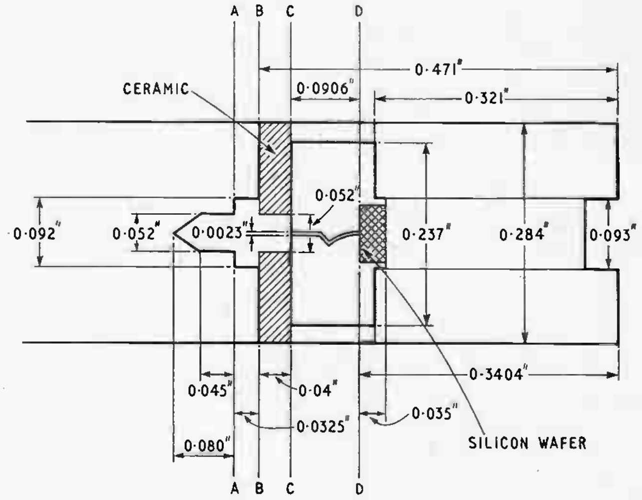
The dimensions of the CV2226 are given in Fig. 1. The structure consists of an outer hollow cylindrical case closed at one end by a cylinder of brass on which is fixed a small silicon wafer; a 'crimped' whisker of diameter 0·0023 in. and length 0·0906 in. has one end pressed against the silicon to form the rectifying contact while the other end terminates in a brass input pin supported by means of a ceramic washer so that it is concentric with the outer case. The admittance of the crystal is usually referred to the plane A–A.

The admittance seen at A–A is therefore the admittance of the equivalent circuit of the point contact itself transformed through the following small lengths of transmission line.

Whisker Section

For the purpose of calculation the 'crimp' in the whisker, which is to ensure mechanical stability, was ignored, and the whisker assumed to be straight. This section is therefore an air-spaced transmission line of length $l_3 = 0{\cdot}0906$ in. whose inner and outer conductors have diameters 0·0023 in. and 0·237 in. respectively.

Fig. 1. *Dimensions of CV*2226



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* *Research Laboratories, The General Electric Company Limited, Wembley, England*
† J. E. Houldin. Unpublished work.

The characteristic impedance of the line, $Z_3 = 1/Y_3$, is 278 Ω.

Ceramic Section

The ceramic washer is assumed to have a dielectric constant $\kappa = 6$. This section is therefore a dielectric-spaced transmission line of electrical length $l_2' = \sqrt{\kappa}$ 0·04 in., the diameters of the inner and outer conductors being 0·052 in. and 0·284 in. respectively. The characteristic impedance $Z_2 = 1/Y_2$ of this line is 41·5 Ω.

Input Section

The input section, between the ceramic and the plane A–A is an air-spaced transmission line of length 0·0325 in. with inner and outer conductors of diameter 0·092 in. and 0·284 in. respectively. The characteristic impedance $Z_1 = 1/Y_1$ of the line is 68 Ω.

It will be noted that at the ends of the line sections, discontinuous changes occur in the inner conductor diameter or outer conductor diameter or both. Thus, at the rectifying contact the inner diameter changes from that of the whisker to zero; at plane C–C both inner and outer diameters change while at plane B–B a change occurs in the inner diameter. It is shown in Reference 1 that the effect of such discontinuities on the principal wave can be simulated by capacitances placed across the transmission lines at the planes of the

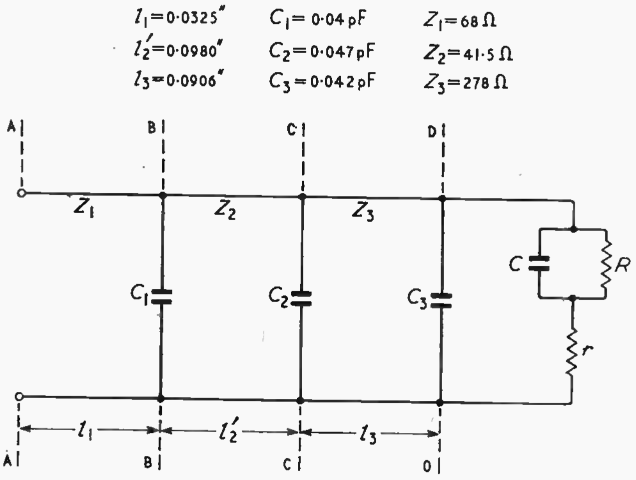
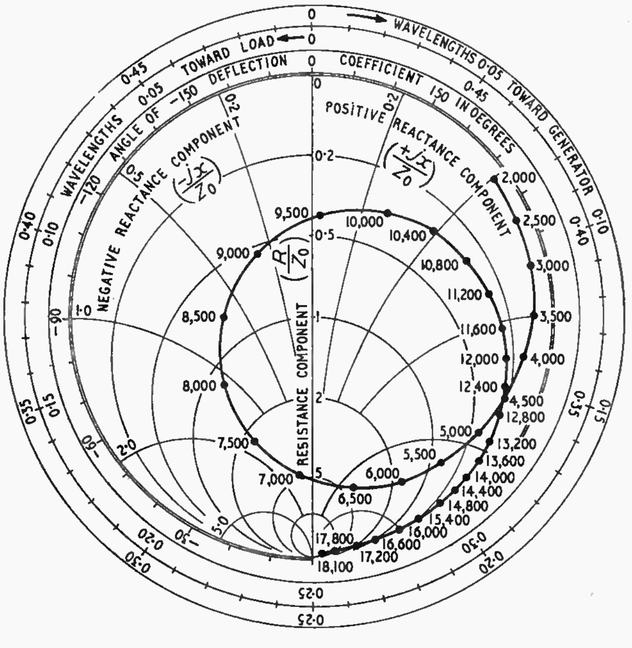


Fig. 2. *Equivalent circuit of CV*2226

Fig. 3. *Computed crystal admittance relative to* 1/68 *mho with* $r = 30\ \Omega$, $R = 3{,}000\ \Omega$ *and* $C = 0\cdot15\ pF$



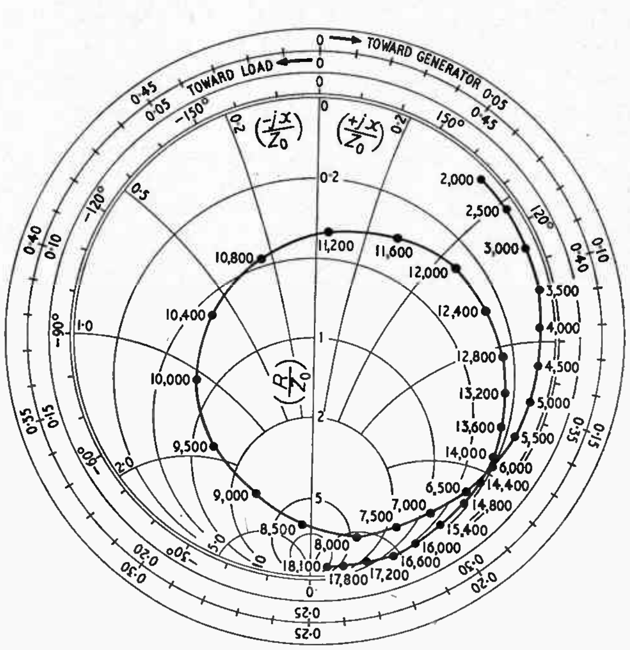
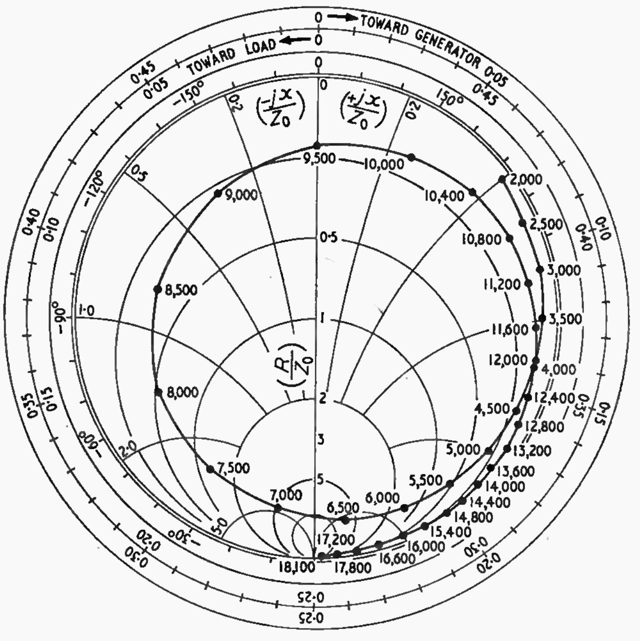


Fig. 4. *Computed crystal admittance relative to* 1/68 *mho with* $r = 30\ \Omega$, $R = 3{,}000\ \Omega$ *and* $C = 0\cdot075\ pF$

Fig. 5. *Computed crystal admittance relative to* 1/68 *mho with* $r = 10\ \Omega$, $R = 3{,}000\ \Omega$ *and* $C = 0\cdot15\ pF$



discontinuities and graphs are given from which the magnitudes of these capacitances can be easily read. The simplest equivalent circuit[2] of the rectifying contact itself which takes into account the known physical parameters at the metal–semiconductor contact is a spreading resistance r in series with the parallel combination of video resistance R and the barrier capacitance C. The assumed equivalent circuit for calculating the admittance is therefore that shown in Fig. 2, the capacitances $C_1 = 0{\cdot}04$ pF, $C_2 = 0{\cdot}047$ pF and $C_3 = 0{\cdot}042$ pF being the calculated discontinuity capacitances at the planes B–B, C–C and D–D respectively.

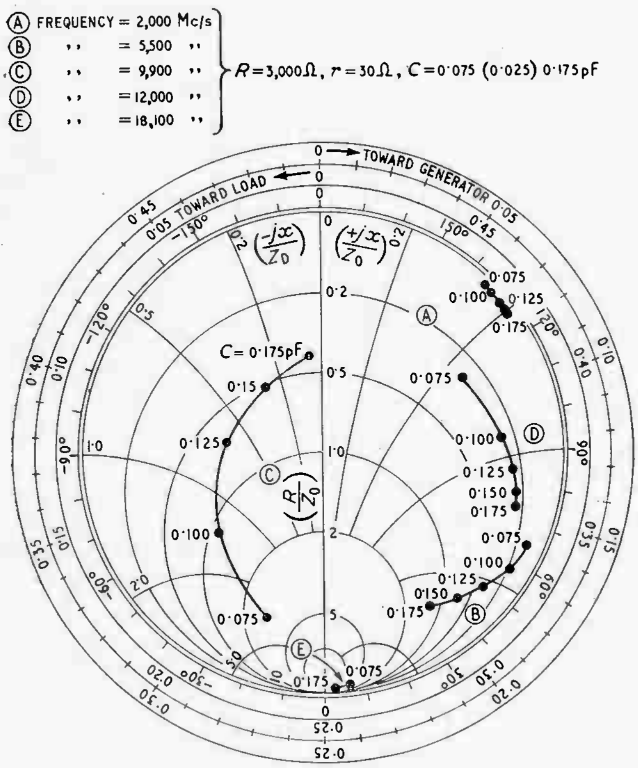
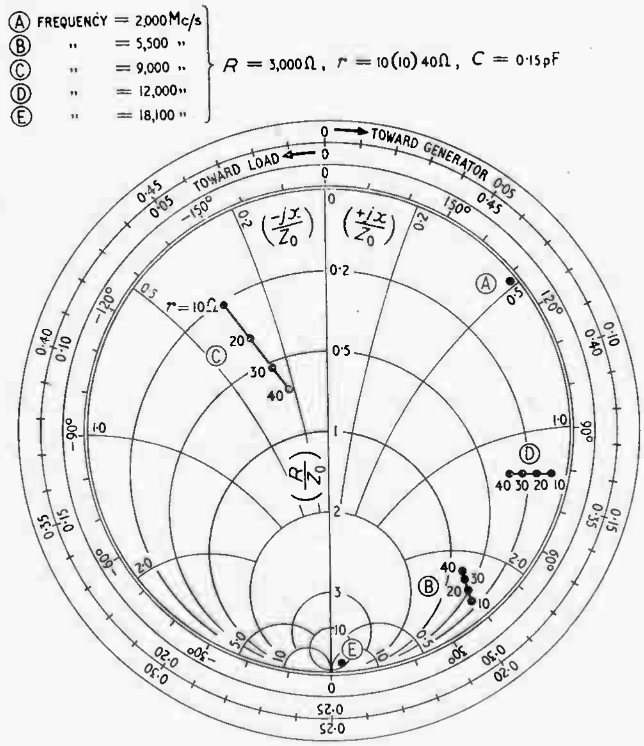


Fig. 6. *Variation with C of computed crystal admittance relative to 1/68 mho. Curve A = 2,000 Mc/s; B = 5,500 Mc/s; C = 9,000 Mc/s; D = 12,000 Mc/s; E = 18,100 Mc/s*

Fig. 7. *Variation with r of computed crystal admittance relative to 1/68 mho. Curve A = 2,000 Mc/s; B = 5,500 Mc/s; C = 9,000 Mc/s; D = 12,000 Mc/s; E = 18,100 Mc/s*



Results

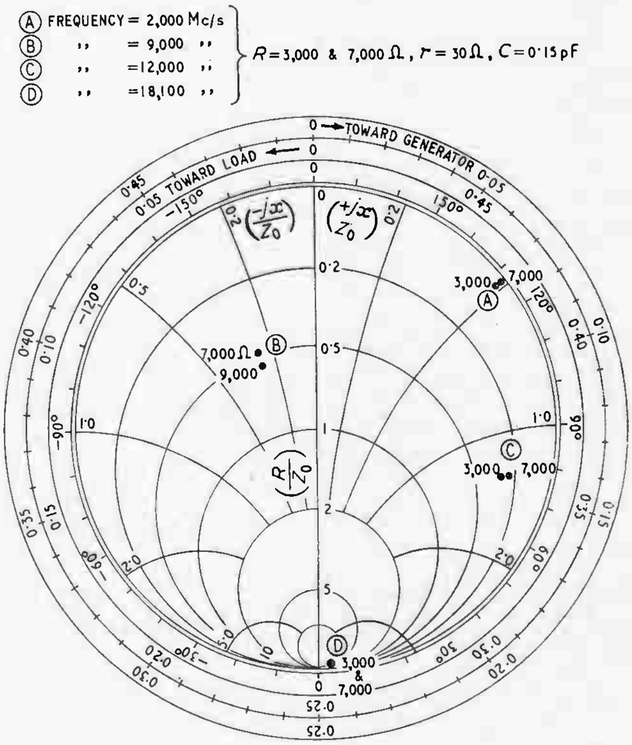
The calculated admittance plot for the frequency range 2,000 to 18,000 Mc/s for $r = 30\,\Omega$, $R = 3{,}000\,\Omega$ and $C = 0{\cdot}15$ pF is shown in Fig. 3. Fig. 4 shows the effect of reducing C to $0{\cdot}075$ pF, leaving r and R constant and Fig. 5 of reducing r to $10\,\Omega$, C and R remaining unaltered. Comparison of the three graphs shows that:

(1) At a fixed frequency, reducing C produces only a small change in the magnitude of the reflection coefficient of the crystal but does result in an anticlockwise rotation of the phase angle, the change in angular position being most marked in the 9,000 Mc/s region.

(2) Reducing r leaves the phase angle at a fixed frequency almost unchanged but increases the magnitude of the reflection coefficient; i.e., the point moves radially outwards towards the edge of the chart. Again, the effect is most noticeable in the 9,000 Mc/s region.

The effects are brought out more clearly in Figs. 6 and 7 in which for selected frequencies throughout the

Fig. 8. *Variation with R of computed crystal admittance relative to 1/68 mho. Curve A = 2,000 Mc/s; B = 9,000 Mc/s; C = 12,000 Mc/s; D = 18,100 Mc/s. r = 30 Ω, C = 0·15 pF, R = 3,000 and 7,000 Ω*



range 2–18 kMc/s the admittance variations to be expected from changes in C and r separately are shown. Thus it is seen that at 9,000 Mc/s varying C from 0·175 pF to 0·075 pF produces an angular rotation of almost 180°, while varying r from 40 Ω to 10 Ω reduces the v.s.w.r. relative to a 68-Ω line from 0·65 to just under 0·2. Variation of R in the range 3,000–7,000 Ω produces very little change in the admittance even at the lower frequencies where the bypassing effect of C is least; this is shown in Fig. 8. Further calculations have shown that R would have to be reduced to a few hundred ohms before any significant change in the admittance occurred.

Comparison of Computed and Experimental Results

Measurements made on CV2226 crystals during a period of two years were collected together and an attempt made to assess how well the assumed equivalent circuit described the measured admittances. Measurements were available at regular frequency intervals in the range 2,500–17,000 Mc/s; there were at least 10 measurements at each frequency and at some frequencies as many as 50. The admittance of an 'average crystal' was obtained by finding the mean of the minimum positions and v.s.w.r. values of all the available crystal measurements at each frequency. This seems a more satisfactory method of averaging than taking the mean of the admittances; if one crystal admittance point happens to occur at a point on the chart where either its real or imaginary part is very large, while the rest of the batch has only moderately large real and imaginary parts, the resulting average will be dominated by the one measurement.

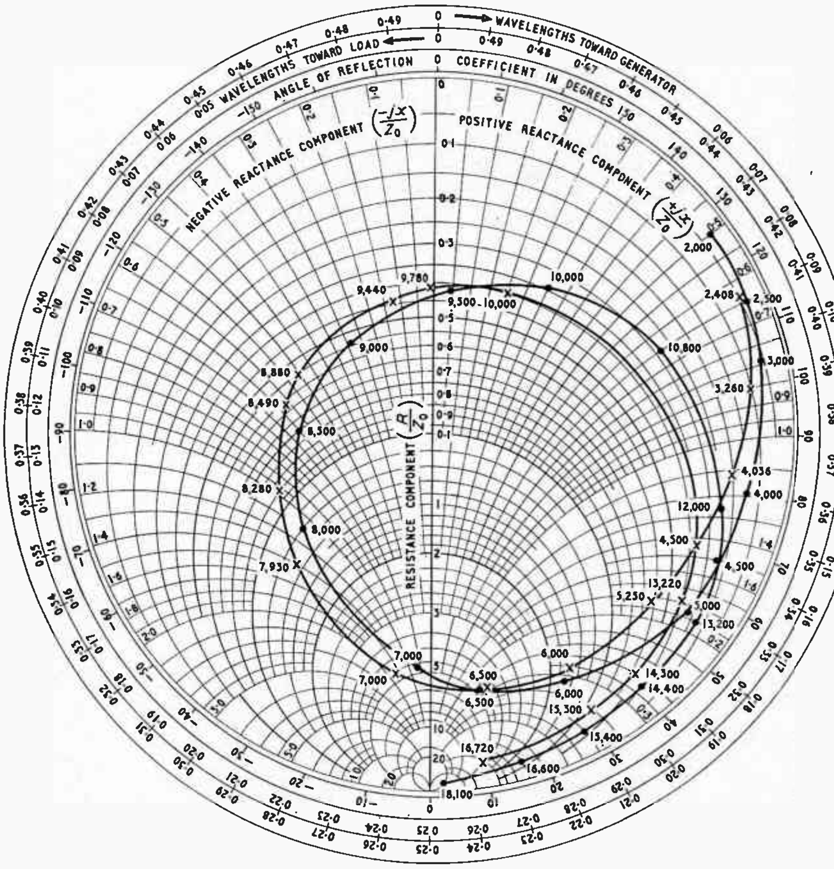


Fig. 9. *Comparison of 'average' measured admittance of CV2226 with a computed crystal admittance. Curve ●—●—● = computed curve with r = 30 Ω, R = 3,000 Ω C = 0·15 pF; Curve ×—×—× = 'average' measured admittance of CV2226 crystals. Each point of curve corresponds to at least 10 measurements. Frequencies are indicated in Mc/s. The admittance plot is normalized to 1/68 mho*

The measured 'average admittance' obtained in this manner is plotted in Fig. 9, and on the same graph the calculated admittance corresponding to $r = 30\,\Omega$, $R = 3{,}000\,\Omega$ and $C = 0{\cdot}15$ pF. The similarity of the two plots over the whole frequency range is quite striking.

A further check on the usefulness of the assumed equivalent circuit is to see if the spread in measured admittances of a batch of crystals at a given frequency can be accounted for by a suitable variation in the crystal parameters. The two sets of measurements chosen for investigation were at 9,140 Mc/s and 5,250 Mc/s. The spread in the twelve measurements made at each of these frequencies is shown in Fig. 10. The parameter C produces the greatest change in calculated admittance and the curves of Fig. 10 show the computed variation in admittance as C changes from 0·175 pF to 0·075 pF, r and R being held constant at 30 and 3,000 Ω respectively. It is seen that the measured and calculated admittance values spread over a similar range of values, the agreement being very good for the higher values of C. The agreement would not be

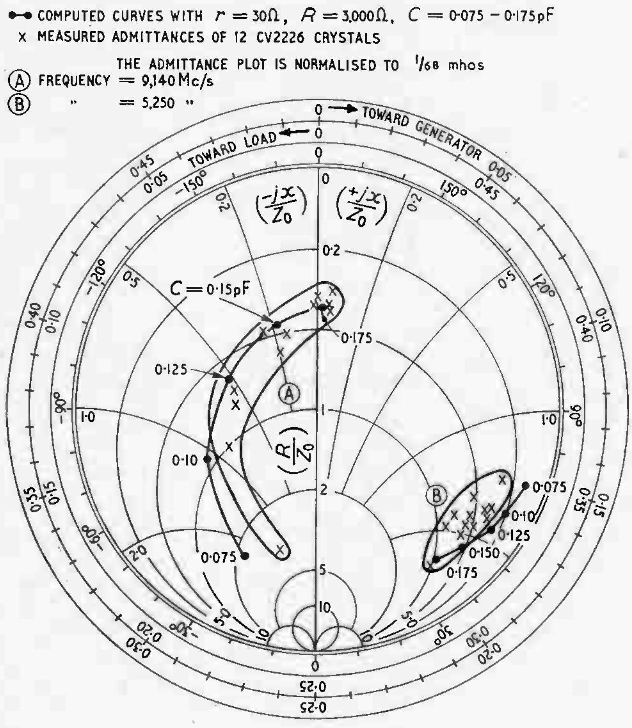


Fig. 10. *Comparison of measured spread in admittance of CV2226 crystals with computed spread due to variation of C at 9,140 and 5,250 Mc/s. Curve ●—●—● computed curves with $r = 30\ \Omega$, $R = 3{,}000\ \Omega$, $C = 0{\cdot}075 - 0{\cdot}175$ pF; Points shown × are measured admittances of 12 CV2226 crystals. The admittance plot is normalized to 1/68 mho*

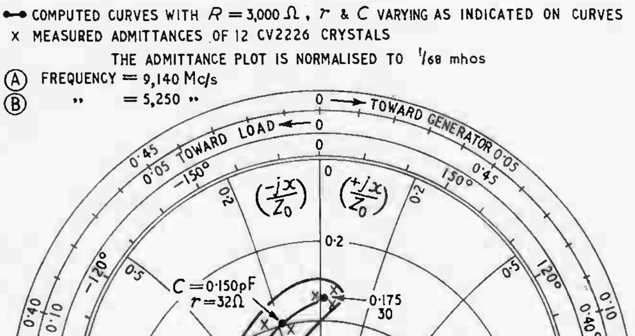


Fig. 11. *Comparison of measured spread in admittance of CV2226 crystals with computed spread due to variation of C and r together at 9,140 and 5,250 Mc/s. Curve ●—●—● = computed curves with $R = 3{,}000\ \Omega$, r and C varying as indicated on curves; Points shown × are measured admittances of 12 CV2226 crystals. The admittance plot is normalized to 1/68 mho*

expected to be complete since in a crystal r and C do not vary independently. If the area of contact between the whisker and silicon slab is assumed to be a circle of radius a, then C is proportional to a^2 while r is inversely proportional to a. To obtain the theoretical curve corresponding to the measurements, r and C must therefore be varied together in an appropriate manner. Assuming the calculated admittance corresponding to $r = 30\ \Omega$, $C = 0{\cdot}175$ pF is a point on the required curve, then as C is decreased from $0{\cdot}175$ pF in the ratio $\alpha : 1$, r must be increased from $30\ \Omega$ in the ratio $\sqrt{\alpha} : 1$. The experimental results of Fig. 10 are re-plotted in Fig. 11 for comparison with the computed curve obtained by varying r and C in the manner described above. The agreement at 9,140 Mc/s is extremely good and at 5,250 Mc/s reasonably good.

Current Sensitivity

If B_0 and B are respectively the low- and high-frequency current sensitivity, the ratio B/B_0 is given[2] approximately by $B/B_0 = 1/(1 + \omega^2 C^2 rR)$. Assuming the contact area between whisker and silicon wafer is a circle of radius a, $C \propto a^2$, $R \propto 1/a^2$, $r \propto 1/a$, and therefore $C^2 rR \propto a$. For a high value of B, a is required to be as small as possible; this corresponds to a low value of C and a high value of r. Since r and C are the parameters which affect the admittance most there should be a correlation between measured sensitivity and admittance; the most suitable frequency range for testing this is in the neighbourhood of 9,000 Mc/s where the measured spread in admittance is greatest. Referring to the results at 9,140 Mc/s plotted in Fig. 11, one would expect the more sensitive crystals to have admittance points which lie at the bottom of the area marked on the chart to represent the measured spread in admittance. Unfortunately, no measurements at 9,000 Mc/s have been made here of both B and the crystal admittance for the same batch of crystals, but measurements made by C. L. Silver of R.A.E. confirm that the expected correlation exists.

Conclusion

It is concluded that the simple equivalent representation of the rectifying point-contact by the spreading resistance r, in series with the parallel combination of video resistance R and barrier capacitance C, is sufficient to predict the admittance of the crystal over the entire band 2,000–18,000 Mc/s, and also to account for the spread in measured admittance of a batch of crystals at a given frequency.

Acknowledgements

The authors wish to thank F. W. Parker of G.E.C. Computing Service for preparing the digital computer programme. They also wish to thank the Admiralty for permission to publish this paper.

REFERENCES

[1] J. R. Whinnery, H. N. Jameson and T. E. Robbins. "Coaxial Line Discontinuities", *Proc. Inst. Radio Engrs*, Vol. 32, No. 11.
[2] H. C. Torrey and C. A. Whitmer. "Crystal Rectifiers", *M.I.T.*, Radiation Laboratory Series, Vol. 15.

The Transactor

AN IDEALIZED ACTIVE NETWORK ELEMENT

By A. W. Keen, M.I.R.E., A.M.I.E.E.*

SUMMARY. *The two-terminal constant-current and constant-voltage generators used in equivalent circuits of active networks are replaced by transmission-type active elements called transactors in order to display more accurately the transmission ('signal flow') properties of such networks. Four variants of the transactor are distinguished and their inter-relationship is established. Justification for the introduction of these idealized active elements is found in the transactor-like properties of thermionic amplifier valves and other widely-used active devices having similar properties, such as transistors.*

In the analysis of electrical systems containing active transmission elements, such as thermionic amplifier valves and transistors, it is customary to represent the electrical properties of these elements by equivalent circuits containing one or more constant-current or constant-voltage generators whose magnitudes and signs are related to voltages or currents occurring elsewhere in the circuit, and to indicate this dependence by assigning an appropriate transfer factor to the magnitude of each generator. While this practice is satisfactory for analytical purposes it is open to objection on topological grounds in so far as no graphical connection is made between the controlled generator and its controlling current or voltage. The idealized generators of conventional network theory are essentially independent single-terminal-pair elements, whereas those needed to represent the activity of valves and analogous devices are essentially two-terminal-pair elements. In this paper it is proposed to recognize this distinction and to call such generators transmission-type active elements, or transactors. It will be seen that four variants exist, between which inter-relationships may be established, all of which are useful in active network analysis, and may be closely approximated by readily available physical elements in the form of particular electronic circuits.

The Impedance Transactor $\left(\vec{Z}\right)$

The impedance matrix equation of an active quadripole, viz.

$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \cdot \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} \qquad \ldots \quad \ldots \quad \ldots \; (1)$$

may be transformed into one having a symmetrical impedance matrix by putting

$$z_{21} = z_{12} + z'_{12}$$

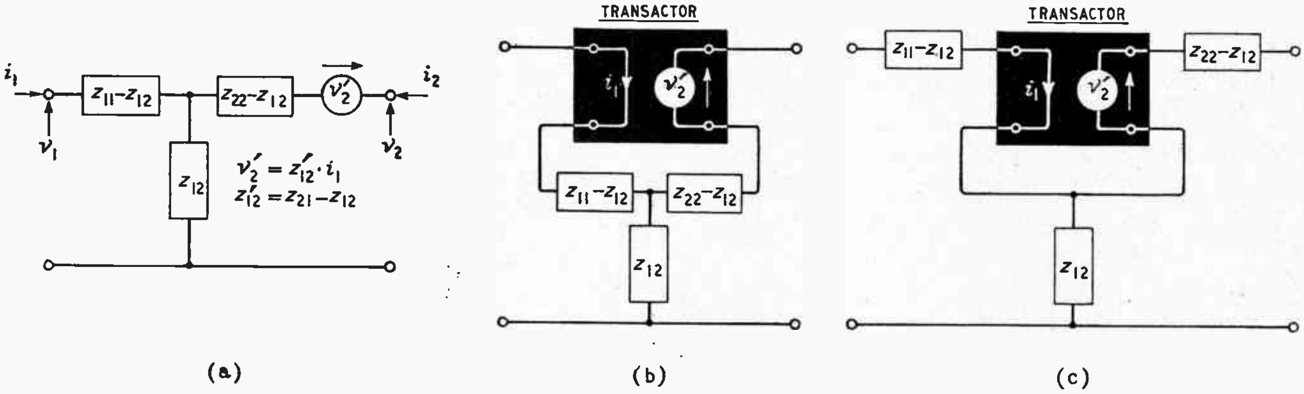


Fig. 1. *A derivation of the impedance transactor: (a) the conventional T-equivalent circuit of the impedance matrix of the non-reciprocal two-terminal-pair network; (b) rearrangement of (a) in which the controlling current and controlled voltage generator are united into an impedance transactor; (c) an alternative rearrangement of (a) which allows the transactor to have a terminal common to each terminal-pair and to be realized in the form of an idealized amplifier valve*

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* *Coventry Technical College*

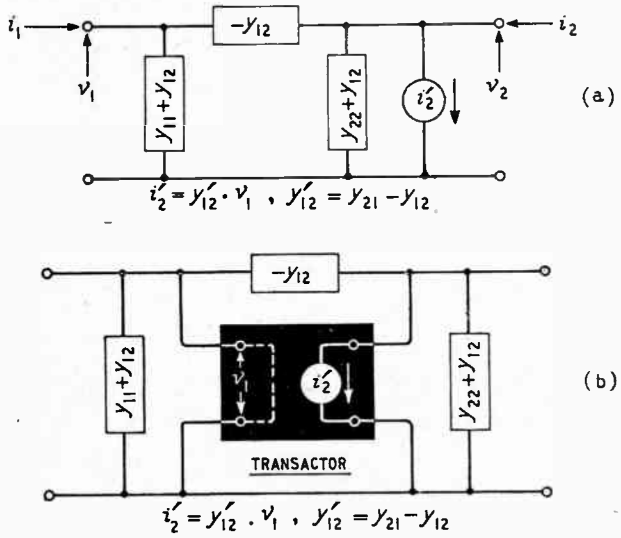


Fig. 2. *A derivation of the admittance transactor; (a) the conventional-equivalent circuit of the admittance matrix of the non-reciprocal two-terminal-pair network [the dual of Fig. 1 (a)]; (b) rearrangement of (a) in which the controlling voltage and controlled generator are united into an admittance transactor which may be realized as an ideal amplifier valve*

and transferring the partial element z'_{12} to the voltage vector, thus:

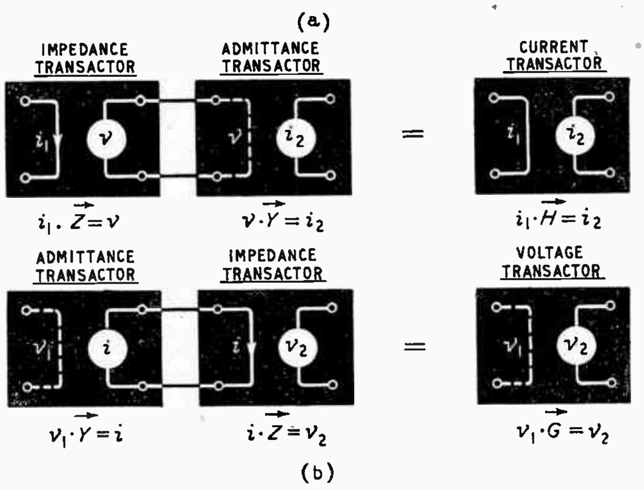
$$\begin{bmatrix} v_1 \\ v_2 - z'_{12} \cdot i_1 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{12} & z_{22} \end{bmatrix} \cdot \begin{bmatrix} i_1 \\ i_2 \end{bmatrix} \quad \ldots \quad \ldots \quad (2)$$

This form is readily interpreted as an equivalent circuit, and is drawn in the conventional manner in Fig. 1 (a) in order to illustrate the point previously made concerning the segregation of the equivalent generator, which accounts for the active property of the network, from the current to which it is related. This dependence may be shown more clearly and accurately by bringing a portion of the current-controlling branch into juxtaposition with the controlled voltage generator and combining the two into a single transmission-type element. This may be done in two ways, as shown at (b) and (c), the one requiring a transmission element having two distinct terminal-pairs, the other allowing each pair to have a common terminal. In both cases the controlling current passes through the input terminal-pair and exerts unilateral control over the voltage made available at the output terminal-pair. It is suggested that this composite element be regarded as irreducible, and that it should not be dissociated in the manner shown in Fig. 1 (a). It is proposed to call this element a transactor of the impedance type since it is characterized by a transfer-impedance parameter (z'_{12}). It will be noted that the general quadripole reduces to the impedance transactor when all three of the remaining passive two-terminal impedance elements become zero, that is, when all four of the elements of the symmetrical matrix in Equ. (2) are zero. The impedance matrix of the impedance transactor is therefore of the form:

$$[Z_T] = \begin{bmatrix} 0 & 0 \\ z & 0 \end{bmatrix}$$

It will be noted that this matrix has zero determinant, so the admittance matrix does not exist.

Fig. 3. *Derivation of the current transactor and voltage transactor by cascade connection of admittance and impedance transactors; (a) an impedance transactor followed by an admittance transactor is equivalent to a single current transactor; (b) the reverse combination yields the voltage transactor*



The Admittance Transactor $\left(\vec{Y}\right)$

The admittance matrix equation of an active quadripole, viz.

$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \cdot \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

may be transformed into one having a symmetrical admittance matrix in a similar manner to that adopted in the previous section on the impedance matrix, by setting

$$y_{21} = y_{12} + y'_{12}$$

and transferring the partial element y'_{12} over to the current vector, thus:

$$\begin{bmatrix} i_1 \\ i_1 - y'_{12} \cdot v_1 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{12} & y_{22} \end{bmatrix} \cdot \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \quad \ldots \quad \ldots \quad (4)$$

The equivalent circuit of this form, drawn in the conventional manner with the equivalent generator detached from the voltage on which it depends, is shown at (a) in Fig. 2. At (b) the generator is provided with an additional terminal pair to which the controlling voltage is applied, and the composite element treated as irreducible. In this case the element effects a unilateral conversion of voltage to current and is specified by a transadmittance factor (y'_{12}). It will therefore be called an admittance transactor. When the passive elements in the remainder of the circuit are all of zero admittance the quadripole reduces to the transactor and has on admittance matrix of the form:

$$[Y_T] = \begin{bmatrix} 0 & 0 \\ y & 0 \end{bmatrix}$$

This matrix is also singular, and has no inverse.

Current and Voltage Transactors $\left(\vec{H},\ \vec{G}\right)$

In so far as a generator may produce either voltage or current, while, in the controlled (i.e., transactor) form, the controlling agency may also be either a voltage of a current, four types of transactor are feasible (Fig. 3). The remaining pair, in which current controls current (current transactor) and voltage controls voltage (voltage transactor), may be derived in various ways. For example, replacement of the generator $z'_{12}\cdot i_1$ and impedance $z_{22}-z_{12}$ in Fig. 1 (a) by the dual combination of a current generator and shunt impedance, prior to association with the controlling branch, yields, in combination with the latter, a current transactor characterized by a current transfer factor. Application of the same method to Fig. 2 (a) leads to the voltage transactor.

Alternatively both may be obtained by cascade connection of admittance and impedance transactors. When an impedance transactor is followed by an admittance transactor the combination may be reduced to a single transactor characterized by the current ratio $H = ZY$; i.e., a current transactor. When the admittance transactor precedes the impedance transactor the resultant is a single voltage transactor of voltage ratio $G = YZ$. Thus, cascade connection of admittance and impedance transactors is non-commutative. See Fig. 3.

Cascaded Transactors

The possibilities of direct interconnection between transactors is limited by disparities between their input and output impedances. A transactor having current output (i.e., the admittance and current forms) may not be followed directly by a type having voltage input (i.e., impedance or voltage forms), because the adjoining impedances are both infinite. It is necessary to interpose a bilateral Z element in order to provide a path for the output current of the first transactor and develop an input voltage for the one which follows.

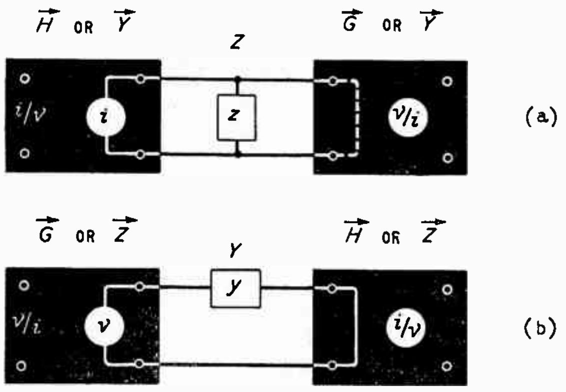


Fig. 4. *The four basic transactors may be cascaded in a variety of ways. In general a coupling bilateral element is required because of impedance disparities. At* (a) *a transactor having a controlled current generator* (*i.e.*, $\vec{H}$ *or* $\vec{Y}$) *develops a p.d. across the bilateral impedance* Z *for application to a voltage-controlled transactor* ($\vec{G}$ *or* $\vec{Y}$); *at* (b) *a transactor having a controlled voltage generator* (*i.e.*, $\vec{G}$ *or* $\vec{Z}$) *delivers a current determined by a bilateral admittance coupling element to a current-controlled transactor* ($\vec{H}$ *or* $\vec{Z}$). *The special cases* $\vec{H}\cdot Z\cdot\vec{G}$ *and* $\vec{G}\cdot Y\cdot\vec{H}$, *using transactors of unit magnitude yield the impedance and admittance transactors* ($\vec{Z}$, $\vec{Y}$) *respectively; i.e., the unilateral transactors convert a bilateral coupling admittance or impedance into a unilateral one*

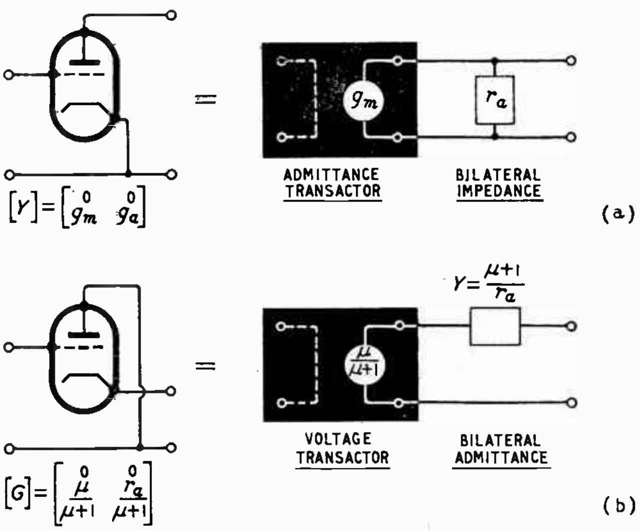


Fig. 5. *The basic transactors are readily realizable in the form of thermionic valve circuits. The simplest examples are:* (a) *the normally-connected* (*i.e., grid-input anode-output*) *amplifier which, with a valve of negligible anode conductance* g_a, *is a close approximation to the admittance transactor;* (b) *the cathode-follower-connected amplifier valve, which, with a valve of high* g_m, *is a good approximation to the unit voltage transactor*

Similarly, a transactor having voltage output cannot be directly cascaded with one needing current input ; a bilateral admittance element must be interposed to prevent the output voltage of the first transactor from being short-circuited by the zero input impedance of the following one. See Fig. 4.

Physical Realization Of Transactors

When choosing a basic element for the purpose of theoretical analysis it is desirable that the element should be an idealized form of some commonly occurring circuit component; otherwise any element suggested by theoretical considerations is unlikely to find general acceptance. An advantage of the transactor in this respect is its ready realizability in the form of a thermionic amplifier valve (Fig. 5). Under idealization, with the hypotheses of linear, negative-grid operation at frequencies sufficiently low to exclude inter-electrode capacitance paths, a normally-connected amplifier valve reduces to an admittance transactor of magnitude g_m, cascaded with a bilateral impedance element of magnitude r_a, which, in the case of a pentode, is usually large enough to be ignored. When connected as a cathode-follower an amplifier valve is equivalent to a voltage transactor of unit magnitude cascaded with a bilateral admittance $(\mu + 1)/r_a$ which is relatively small in the case of a high g_m valve. Again, equality of input and output currents, together with low input and high output impedances, allow the cathode-input amplifier to be regarded as a close approximation to the unit-gain current transactor, particularly when the μ and g_m of the valve are high. Finally, the impedance form of transactor may be realized as a cathode-input amplifier followed by a cathode-follower, or, in a single stage, as a normally-connected amplifier having shunt feedback and a high open-circuit loop gain.

MATHEMATICAL TOOLS

By Computer

Operational Calculus—4: Solution by means of Series

In earlier articles, we have shown how operational calculus can be used to determine the current flowing in a circuit whose impedance is known for certain simple types of input voltage, whether or not the capacitors of the circuit are initially charged and the inductors carry initial currents. We have only given the shortest possible list of time-functions and their p-world counterparts. More extended lists are available in the literature but, even so, cases may occur in which we cannot easily find the time-world counterpart of a p-expression explicitly by algebraic manipulation. It is, however, usually possible to obtain a solution in the form of an infinite series by expanding the p-equation into a power series in $1/p$ and then interpreting it into a series in t by means of the fact that $1/p^n$ is the p-world counterpart of $(t^n/n\,!)$.

A solution in this form is not always useful, of course. It depends on what we want to know. Sometimes the first few terms will tell us what we want and then the method is very useful indeed. Generally, the method is useful when we are only interested in what happens just after the application of a step or other wave and it is not much use for finding out what happens a long time afterwards.

First let us consider a simple case in which we have already obtained the correct answer—when a voltage, v_0 is applied suddenly to the simple *RC* circuit of Fig. 1. The answer that we then obtained was that the p-world counterpart $V_R\,(p)$ of the voltage $V_R(t)$ across R was given by

$$V_R(p) = \frac{pv_0}{p+\alpha} \text{ where } \alpha = 1/CR \quad .. \quad .. \quad (1)$$

From the table of corresponding functions given in an earlier article we deduced

$$V_R(t) = v_0\, e^{-\alpha t} \quad .. \quad .. \quad .. \quad .. \quad (2)$$

If, however, the right-hand side of (1) had not been listed, we could have obtained the same result by expanding $p/(p + \alpha)$; that is to say, writing

$$V_R(p) = \frac{pv_0}{p+\alpha} = \frac{v_0}{1+\alpha/p}$$

$$= v_0\left(1 - \frac{\alpha}{p} + \frac{\alpha^2}{p^2} - \frac{\alpha^3}{p^3} + \ldots\right) \text{to infinity } (3)$$

Replacing $1/p^r$ by $t^r/r\,!$ according to the list gives

$$V_R(t) = v_0\,(1 - \alpha t + \alpha^2 t^2/2\,! - \alpha^3 t^3/3\,! + \ldots) \quad (4)$$

$$= v_0\, e^{-\alpha t} \quad .. \quad .. \quad .. \quad .. \quad (5)$$

in complete agreement with (2). Since $1/p^r$ corresponds to $t^r/r\,!$, the series for $V_R(t)$ has factorials in the denominator of each term and is convergent for all values of t in spite of the fact that, strictly, (3) does not apply unless $|p| < \alpha$. There is seldom any difficulty about the convergence of series in the time-world derived in this way and, if a safeguard is needed, it is usually relatively easy to verify whether any particular solution suggested by this method is correct or not. The difficulty is to know what type of solution to expect. Operational calculus in general, and the above-mentioned method of series expansion in particular can, to some extent, be regarded as a means of making an enlightened guess of the solution.

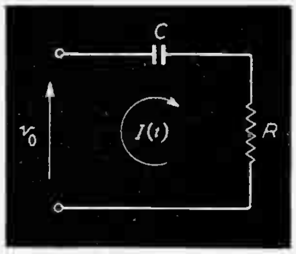


Fig. 1. *Simple RC circuit*

A solution for the current resulting from the application of a step-voltage to the series *LCR* circuit of Fig. 2 could also have been obtained by means of a series. In an earlier article we found that the current $I(t)$ and its p-world counterpart $I(p)$ were given by

$$I(p) = \frac{v_0}{R + pL + 1/pC} = \frac{pv_0}{L(p^2 + 2\alpha p + \omega_0^2)} \quad (6)$$

$$I(t) = \frac{v_0}{\omega L}\, e^{-\alpha t} \sin \omega t \quad .. \quad .. \quad .. \quad .. \quad (7)$$

where $\alpha = R/2L$, $\omega_0^2 = 1/LC$ and $\omega = (\omega_0^2 - \alpha^2)^{\frac{1}{2}}$, (8)
assuming that $\omega_0 > \alpha$; the form of $I(t)$ was different when $\omega_0 \leqslant \alpha$ but this is irrelevant for our present purpose of deriving (7) by means of a series expansion in the case to which (7) applies.

In (6) take out the factor v_0/L, and then divide $(p^2 + 2\alpha p + \omega_0^2)$ into p by the ordinary long-division process.

We thus find

$$I(p) = \frac{v_0}{L}\Big[1/p - 2\alpha/p^2 + (4\alpha^2 - \omega_0^2)\,/p^3$$

$$+ 4\alpha\,(\omega_0^2 - 2\alpha^2)\,/\,p^4 + \ldots\Big] \quad (9)$$

stopping arbitrarily at the term in $1/p^4$. Translating this into the time-world, we have

$$I(t) = \frac{v_0}{L}\Big[t - \alpha t^2 + t^3(4\alpha^2 - \omega_0^2)/6$$

$$+ t^4\alpha(\omega_0^2 - 2\alpha^2)/6 + \dots\Big] \quad (10)$$

and it can be verified that (10) is the same as (7) by expanding the series product

$$I(t) = \frac{v_0}{\omega L}\left(1 - \alpha t + \frac{\alpha^2 t^2}{2} - \frac{\alpha^3 t^3}{6} + \dots\right)$$

$$\left(\omega t - \frac{\omega^3 t^3}{6} + \dots\right) \quad (11)$$

as far as the term in t^4, and bearing in mind the definition of ω in (8). It is worth noting that (10) is the same whatever the relative values of α and ω_0, although the explicit answer (7) is only valid if $\omega_0 > \alpha$ and has to be modified in other cases. If an explicit answer like (7) is available, it is usually preferable to obtain it; on the other hand, a series expression like (10) may be obtained easily when the corresponding explicit expression was either unknown or extremely complicated.

There is no reason why the above long-division technique should not be used in cases where the applied voltage is not a step-function, or when the circuit is not initially 'dead'. The long-division technique is merely an algebraic manipulation of the appropriate expression for $I(p)$. The validity of this manipulation is not in any way connected with the method by which $I(p)$ is derived.

In some problems, such as the compensation of circuits at low frequencies, series expansion may give us the information we require and a more explicit solution in closed form is unnecessary even if such a solution is available. Thus in the case of the circuit of Fig. 1 when we derive $V_R(t)$ in the form (4), we may only wish to ensure that $V_R(t)$ is as constant with time as possible. This requires that α shall be as small as possible, or CR as large as possible, and this fact is just as obvious from the series form (4) of $V_R(t)$ as from the explicit form (2). In more complicated cases of this kind, it may only be necessary to derive $V_R(p)$ by long division as described in the form

$$V_R(p) = a_0 + a_1/p + a_2/p^2 + \dots \quad \dots \quad \dots \quad (12)$$

and choose the circuit elements under our control so that as many of the successive quantities a_1, a_2 .... as possible are zero.

As an example, consider the circuit of Fig. 3. For simplicity, we shall regard V$_1$ as a constant-current device delivering a current $g_m v_{g1}$ where g_m is the mutual conductance of V$_1$, and we shall only consider the case when v_{g1} is a step-voltage. The impedances of the two branches are

$$Z_1 = R_1 + \frac{R_3}{1 + pC_1R_3} = R_1\frac{p + [1 + (R_1/R_3)]/C_1R_1}{p + (R_1/R_3)/C_1R_1} \quad (13)$$

$$Z_2 = R_2 + 1/pC_2 = R_2[p + 1/(C_2R_2)]/p \quad \dots \quad (14)$$

Hence the p-world counterpart of the anode voltage is

$$v_a = -g_m v_{g1}\frac{Z_1 Z_2}{Z_1 + Z_2} \approx -g_m v_{g1} Z_1 \text{ if } Z_1 \ll Z_2 \quad (15)$$

so that the grid voltage v_{g2} of the second valve is

$$v_{g2} = v_a R_2/Z_2 \approx -g_m v_{g1}\frac{Z_1 R_2}{Z_2} \text{ if } Z_1 \ll Z_2 \quad \dots \quad (16)$$

It follows that

$$\frac{v_{g2}}{v_{g1}} = -g_m R_1 \cdot \frac{p + a}{p + b} \cdot \frac{p}{p + c} \quad \dots \quad \dots \quad \dots \quad (17)$$

where

$$a = \frac{1 + R_1/R_3}{C_1 R_1};\ b = \frac{R_1/R_3}{C_1 R_1} = \frac{1}{C_1 R_3};\ c = \frac{1}{C_2 R_2} \quad (18)$$

If R_3 is sufficiently small, (17) simplifies to

$$\frac{v_{g2}}{v_{g1}} = -g_m R_1 \frac{p}{p + c} \quad \dots \quad \dots \quad \dots \quad \dots \quad (19)$$

so that, if v_{g1} is a step-voltage v_0 applied at $t = 0$,

$$v_{g2}(t) = -g_m v_0 R_1 e^{-ct} = -g_m v_0 R_1 e^{-t/C_2R_2} \quad (20)$$

In series form, derived from (19) or (20), we therefore have

$$v_{g2}(t) = -g_m v_0 R_1 \left[1 - \frac{t}{C_2 R_2} + \frac{1}{2}\frac{t^2}{C_2^2 R_2^2} - \dots\right] \quad (21)$$

An amplifier of this kind may have to handle a square-topped pulse of duration τ say. It will only do this satisfactorily if the response (21) to a step-wave has not fallen substantially, say by 5%, when $t = \tau$. The largest value of t/C_2R_2 in which we are interested is thus about 0·05, and the next term in the series in (21) then has the very small value 0·00125. Thus, only the first t-term of the series (21) matters. This term is often called the relative sag, or sag for short; we can therefore write

$$\text{sag} = t/C_2R_2 \quad \dots \quad \dots \quad \dots \quad \dots \quad \dots \quad (22)$$

In Fig. 3, R_3 [which was neglected in deriving (19)] and C_1 are included to improve the performance, and v_{g2}/v_{g1} is therefore given by (17) instead of (19). We can expand (17) as a power series in $1/p$ by long division, as already mentioned; it will be sufficient to stop at the term in $1/p^3$. But before carrying out the division, it is worth observing that we want to have no term in $1/p$ in the expansion if this can be arranged. Now

$$\frac{p(p+a)}{(p+b)(p+c)} = \frac{p^2 + ap}{p^2 + (b+c)p + bc} \quad \dots \quad \dots \quad (23)$$

so that there will clearly be no term in $1/p$ if the coefficients of p in numerator and denominator are equal, that is, if

$$a = b + c \quad \text{or} \quad C_1 R_1 = C_2 R_2. \quad \dots \quad \dots \quad (24)$$

In this case

$$\frac{p(p+a)}{(p+b)(p+c)} = 1 - \frac{bc}{p^2 + (b+c)p + bc}$$

$$= 1 - \frac{bc}{p^2} + \frac{bc(b+c)}{p^3} + \dots \quad (25)$$

so that, if v_{g1} is a step-voltage v_0 as assumed before,

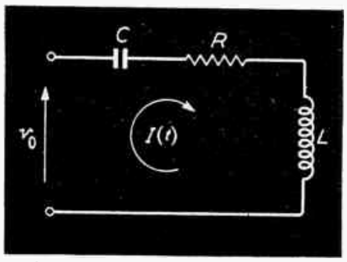


Fig. 2. *Series LCR circuit*

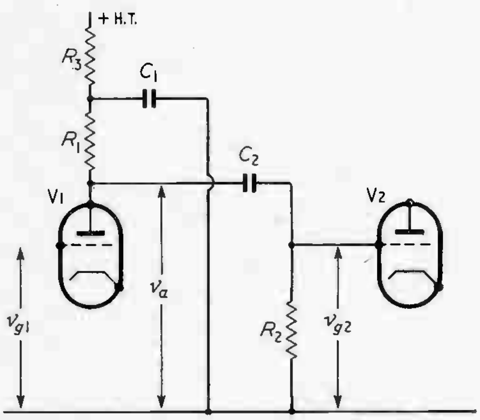


Fig. 3. *Intervalve coupling in which R_3C_1 provide some compensation for R_2C_2*

we can obtain $v_{g2}(t)$ by putting $t^2/2$ instead of $1/p^2$ and $t^3/6$ instead of $1/p^3$ in (25). We thus find

$$v_{g2}(t) = -g_m v_0 R_1 \left[1 - \frac{1}{2} bct^2 + \frac{1}{6} bc(b+c)\,t^3 - \ldots\right] \tag{26}$$

Substituting from (18) and (24), this reduces to

$$v_{g2}(t) = -g_m v_0 R_1 \left[1 - \frac{1}{2}\frac{R_1}{R_3}\frac{t^2}{C_2{}^2 R_2{}^2} + \frac{1}{6}\frac{R_1}{R_3}\left(1 + \frac{R_1}{R_3}\right)\frac{t^3}{C_2{}^3 R_2{}^3} + \ldots\right] \tag{27}$$

or, expressed in terms of sag,

$$\text{sag} = \frac{1}{2}\frac{R_1}{R_3}\frac{t^2}{C_2{}^2 R_2{}^2}\left[1 - \frac{1}{3}\left(1 + \frac{R_1}{R_3}\right)\frac{t}{C_2 R_2} + \ldots\right] \tag{28}$$

For small values of sag, the bracketed term in t in (28) is usually negligible. Clearly R_3 should be made as large as possible ; if it were infinite, b would become zero and a and c would be equal in (18), so v_{g2}/v_{g1} in (17) would be $-g_m R_1$ and compensation would be perfect. It is often impracticable to make R_3 greater than $2R_1$. If $R_3 = 2R_1$, (28) reduces to

$$\text{sag} \approx \frac{t^2}{4C_2{}^2 R_2{}^2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \tag{29}$$

whereas the sag in the uncompensated case ($R_3 = 0$) was given by (22). For a given value of C_2R_2 and a given sag, the ratio of the time t_1 given by (22) at which that sag occurs in an uncompensated circuit to the time t_2 given by (29) at which it occurs in the compensated circuit (with $R_3 = 2R_1$) is $\frac{1}{2}\sqrt{(\text{sag})}$, so that the compensated circuit can deal with a pulse $2/\sqrt{(\text{sag})}$ times as long. For 1% sag, this means 20 times as long. It must be pointed out that the ratio $2/\sqrt{(\text{sag})}$ is derived on the assumption that the time for a given sag in the compensated case is derived from (29) and not from (28), and in the uncompensated case from (22), so that only the first term of (21) is taken into account. For values of sag of the order 1%, the error involved is not serious whereas, for a sag of the order of 5%, the error is appreciable when $R_3 = 2R_1$. (29) and (22) can be regarded as adequate for practical purposes.

The exact solution of (17) when v_{g1} is a step-voltage v_0 applied at $t = 0$ can be found by writing

$$\frac{p(p+a)}{(p+b)\,(p+c)} = p\left[\frac{-b+a}{(p+b)\,(-b+c)} + \frac{-c+a}{(-c+b)\,(p+c)}\right] \tag{30}$$

and the time-expression corresponding to the right-hand side of (30) is

$$\frac{a-b}{c-b}\,e^{-bt} + \frac{a-c}{b-c}\,e^{-ct} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \tag{31}$$

so that

$$v_{g2} = -\frac{g_m R_1 v_0}{c-b}\left[(a-b)\,e^{-bt} - (a-c)\,e^{-ct}\right] \quad \ldots \tag{32}$$

Expanding the exponentials in (32), the term independent of t inside the square brackets is clearly $(c-b)$, the term in t is $(c-b)\,(a-b-c)\,t$, the term in t^2 is $\{(a-b)\,b^2 - (a-c)\,c^2\}\,t^2/2\,!$ and the term in t^3 is $\{(a-c)\,c^3 - (a-b)\,b^3\}\,t^3/3\,!$. The t-term shows that $a = b + c$ and the other terms then given complete agreement between (32) and (26). Although in this case the exact solution (32) was reasonably easy to obtain, (26) gave all the information required and involved nothing more complicated than algebraic long division.

MANUFACTURERS' LITERATURE

Ardente Electronic Miniature Components. Pp. 50. Details of earphones, switches, transformers and potentiometers.
Ardente Acoustic Laboratories Ltd., 8-12 *Minerva Road, North Acton, London, N.W.*10.

Sentercel 'Q' type Unistors. Pp. 28.
Sentercel Contact Cooled Rectifiers. Pp. 4.
Sentercel Silicon Rectifiers. Pp. 8.
Standard Telephones & Cables Ltd., Rectifier Division, Harlow, Essex.

Siemens Selenium Rectifiers. Pp. 24. Deals with contact-cooled and miniature wire-in types.
R. H. Cole (Overseas) Ltd., 2 *Caxton Street, Westminster, London, S.W.*1.

Better Air. Pp. 28.
Fans by Air Control. Pp. 12.
Roll-O-Matic Air Filter. Pp. 8.
Small Blowers, Cooling Fans, Dust Filters. Pp. 28.
Electro-Mist Precipitator. Pp. 4.
Foundry Dust Control Data. Pp. 8.
Air Control Installations Ltd., Ruislip, Middx.

Computer for Cable Problems, Type 450. Leaflet on analogue computer for power-cable calculations.
The Addison Electric Company Ltd., 10-12 *Bosworth Road, London, W.*10.

Relays, Solenoids and Contactors. Two leaflets.
Magnetic Devices Ltd., Exning Road, Newmarket, Suffolk.

Lustraphone. Catalogue of microphones and allied equipment. Pp. 20.
*Lustraphone Ltd., St. George's Works, Regents Park Road, London, N.W.*1

Copper Clad Bakelite Laminated for Printed Circuits. Pp. 6. General notes on printed circuits and specifications of Bakelite materials.
Bakelite Ltd., 12-18 *Grosvenor Gardens, London, S.W.*1.

Catalogue of 'Astronic' Small Power Amplifiers, Transformers and Chokes.
Associated Electrical Engineers Ltd., Dalston Gardens, Stanmore, Middx.

The Non-Destructive Testing of Engineering Materials (2nd Edition). Pp. 24. Deals with ultrasonic techniques. Bibliography with 60 references.
A. E. Cawkell, 6-8 *Victory Parade, The Broadway, Southall, Middx.*

FM-FM Telemetering

ANALYSIS OF THE FREQUENCY SPECTRUM OF A DOUBLE FREQUENCY-MODULATED WAVE

By E. S. Cassedy, Jr.*

In recent years multiplexing of many information channels on to a single carrier has been used in telephony[1] and telemetry.[2] There are many possibilities for accomplishing this multiplexing, all of which may be separated into two classes, frequency division and time division. Within the frequency division class, with which we are here concerned, the f.m.-f.m. system has certain advantages over other systems involving amplitude modulation. The f.m.-f.m. system is one in which each voltage variation or other circuit parameter to be metered frequency-modulates a separate subcarrier. The subcarriers, all operating at different frequencies, are added together and in turn frequency-modulate the main carrier. The subcarriers are sufficiently separated in frequency so that the sidebands due to the first frequency-modulation do not overlap, and are also placed in frequency so that low order harmonics from one subcarrier do not fall in the band pass of other higher frequency subcarriers.

When operated under proper conditions with respect to modulation index, gain-phase-frequency characteristics of filters, and threshholds, the f.m.-f.m. system is superior to amplitude modulated systems as regards signal-to-noise ratio, cross modulation, and distortion. The analysis of these various properties has been surveyed rather exhaustively[2] with respect to signal-to-noise ratio of the overall system, and distortion and intermodulation at the subcarrier level.

The analysis of the main carrier signal has not been carried out, to the best of the author's knowledge. It is the purpose here to give the spectrum created at the carrier level. This will serve to give a rigorous review of the mechanics of modulation in this system, and also to give the necessary expression in the frequency domain for analyzing the distortion and inter-modulation contributed in the modulation and demodulation of the main carrier. In the case of radio telemetry, the most important considerations are distortion in the modulation process due to overmodulation, and intermodulation and distortion in the demodulation process resulting from the gain-phase-frequency characteristic of the intermediate-frequency amplifiers in the receiver.

Analysis of F.M.-F.M. System With a Single Sub-Carrier

We are considering a telemetering system in which the signal voltage to be transmitted frequency-modulates a subcarrier which in turn frequency-modulates the main carrier. The sideband analysis of the case of simple frequency modulation is well known, but will be derived here for the subcarrier for purposes of clarity:

The subcarrier voltage unmodulated is of the form:

$$e_{sc} = E_{sc} \sin \omega_0 t = E_{sc} \sin \theta_0 \qquad .. \quad .. \quad (1)$$

Upon modulation of the subcarrier frequency with a sine wave of angular frequency p, it becomes as a function of time:

$$f(t) = f_0 + \Delta f \cos pt \qquad .. \quad .. \quad .. \quad (2)$$

where $f_0 = \omega_0/2\pi$, and p = signal or intelligence frequency in radians per second.

The subcarrier angular frequency as a function of time is seen to be:

$$\omega(t) = \omega_0 + 2\pi\Delta f \cos pt \qquad .. \quad .. \quad .. \quad (3)$$

The subcarrier phase angle as a function of time must then be:

$$\begin{aligned} \theta(t) &= \int_0^t \omega(\tau)\, d\tau = \int_0^t (\omega_0 + 2\pi\Delta f \cos p\tau)\, d\tau \\ &= \omega_0 t + \frac{2\pi\Delta f}{p} \sin pt \\ &= \omega_0 t + M \sin pt \end{aligned}$$

where M = modulation index

$$= \frac{\text{frequency deviation of subcarrier}}{\text{modulating frequency}}$$

Thus the subcarrier voltage as a function of time when frequency modulated is:

$$e_{sc} = E_{sc} \sin (\omega_0 t + M \sin pt) \qquad .. \quad .. \quad (5)$$

Expansion in a Bessel function series gives the familiar sideband expression[3]:

$$\begin{aligned} e_{sc} = E_{sc} \{ & J_0(M) \sin \omega_0 t \\ & + J_1(M) [\sin (\omega_0 + p)t - \sin (\omega_0 - p)t] \\ & + J_2(M) [\sin (\omega_0 + 2p)t + \sin (\omega_0 - 2p)t] \\ & + J_3(M) [\sin (\omega_0 + 3p)t - \sin (\omega_0 - 3p)t] \\ & + \cdots\cdots\cdots \} \qquad .. \quad .. \quad .. \quad (6) \end{aligned}$$

If a periodic voltage of the form of Equ. (5) is used to frequency-modulate the main carrier, the carrier frequency as a function of time will be:

$$F(t) = F_0 + \Delta F \sin (\omega_0 t + M \sin pt) \qquad .. \quad (7)$$

where F_0 = carrier base-frequency (unmodulated) and ΔF = magnitude of instantaneous deviation of carrrier frequency.

The angular frequency of the carrier is, of course:

$$\begin{aligned} \Omega(t) &= 2\pi F_0 + 2\pi\Delta F \sin (\omega_0 t + M \sin pt) \\ &= \Omega_0 + 2\pi\Delta F \sin (\omega_0 t + M \sin pt) \qquad .. \quad (8) \end{aligned}$$

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The carrier phase-angle as a function of time clearly is:

$$\Theta(t) = \int_0^t [\Omega_0 + 2\pi\Delta F \sin(\omega_0\tau + M \sin p\tau)]\, d\tau \qquad (9)$$

This form is unintegrable in closed form. However, by use of the identity for the sine function from Equ. (5) to Equ. (6), Equ. (9) may be written as:

$$\begin{aligned}\Theta(t) = \Omega_0 t + 2\pi\Delta F \int_0^t \{&\mathrm{J}_0(M) \sin \omega_0\tau \\ &+ \mathrm{J}_1(M)\, [\sin(\omega_0 + p)\tau - \sin(\omega_0 - p)\tau] \\ &+ \mathrm{J}_2(M)\, [\sin(\omega_0 + 2p)\tau + \sin(\omega_0 - 2p)\tau] \\ &+ \mathrm{J}_3(M)\, [\sin(\omega_0 + 3p)\tau - \sin(\omega_0 - 3p)\tau] \\ &+ \ldots\ldots\ldots\ldots \}d\tau \quad \ldots \quad \ldots \quad \ldots \qquad (10)\end{aligned}$$

which, upon integration,* becomes:

$$\begin{aligned}\Theta(t) = \Omega_0 t - \mathrm{J}_0(M)\frac{\Delta F}{f_0}\cos\omega_0 t \\ -\mathrm{J}_1(M)\left[\frac{\Delta F}{f_0 + p/2\pi}\cos(\omega_0 + p)t - \frac{\Delta F}{f_0 - p/2\pi}\cos(\omega_0 - p)t\right] \\ -\mathrm{J}_2(M)\left[\frac{\Delta F}{f_0 + p/\pi}\cos(\omega_0 + 2p)t + \frac{\Delta F}{f_0 - p\pi}\cos(\omega_0 - 2p)t\right] \\ -\mathrm{J}_3(M)\left[\frac{\Delta F}{f_0 + 3p/2\pi}\cos(\omega_0 + 3p)t - \frac{\Delta F}{f_0 - 3p/2\pi}\cos(\omega_0 - 3p)t\right] \\ - \ldots\ldots\ldots \quad \ldots \quad \ldots \quad \ldots \qquad (11)\end{aligned}$$

The substitution of Equ. (11) into the expression for the carrier voltage:

$$e_c = E_c \sin \Theta(t) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (12)$$

would result in the sine of an infinite series, which is not usable. In analogy to the simple f.m. case, however, it is possible to expand the sine function Equ. (12) into a series of terms in the frequency domain. The simple f.m. case was derived from the identity:

$$\begin{aligned}e^{j(\Omega t + Z \sin \omega t)} &= (\cos \Omega t + j \sin \Omega t)\, e^{jZ \sin \omega t} \\ &= (\cos \Omega t + j \sin \Omega t) \cdot \\ &\quad \{\mathrm{J}_0(Z) + 2\,[\mathrm{J}_2(Z)\cos 2\omega t + \mathrm{J}_4(Z)\cos 4\omega t \\ &\quad + \mathrm{J}_6(Z)\cos 6\omega t + \ldots\ldots\ldots] \\ &\quad + j2\,[\mathrm{J}_1(Z)\sin \omega t + \mathrm{J}_3(Z)\sin 3\,\omega t \\ &\quad + \mathrm{J}_5(Z)\sin 6\omega t + \ldots\ldots]\} \qquad (13)\end{aligned}$$

and the well-known $\sin\theta = \mathrm{Im}\, e^{j\theta}$.

Likewise, it can be seen that Equ. (12) with Equ. (11) substituted for $\Theta(t)$ is:

$$\begin{aligned}&\sin\{\Omega_0 t + Z_1 \cos\omega_0 t + Z_2 \cos(\omega_0 + p)t \\ &\quad + Z_3 \cos(\omega_0 - p)t + Z_4 \cos(\omega_0 + 2p)t \\ &\quad + Z_5 \cos(\omega_0 - 2p)t + \ldots\ldots\ldots\} \\ &= \mathrm{Im}\, e^{j\{\Omega_0 t + Z_1 \cos\omega_0 t + Z_2 \cos(\omega_0 + p)t + Z_3 \cos(\omega_0 - p)t\, +\}} \qquad (14)\end{aligned}$$

where

$$Z_1 = \frac{-\Delta F}{f_0}\mathrm{J}_0(M)$$

$$Z_2 = \frac{-\Delta F}{f_0 + p/2\pi}\mathrm{J}_1(M)$$

$$Z_3 = \frac{-\Delta F}{f_0 - p/2\pi}\mathrm{J}_1(M)$$

$$Z_4 = \frac{-\Delta F}{f_0 + p/\pi}\mathrm{J}_2(M)$$

$$Z_5 = \frac{-\Delta F}{f_0 - p/\pi}\mathrm{J}_2(M)$$

$$\begin{matrix}\cdot & \cdot \\ \cdot & \cdot\end{matrix}$$

$$Z_{2m} = \frac{-\Delta F}{f_0 + mp/2\pi}\mathrm{J}_m(M) \qquad m = 0, 1, 2, 3, \ldots\ldots$$

$$Z_{2m+1} = \frac{-\Delta F}{f_0 - mp/2\pi}\mathrm{J}_m(M)$$

Then if we rewrite the sums of exponentials as products, we see that

$$\begin{aligned}&\sin\{\Omega_0 t + Z_1\cos\omega_0 t + Z_2\cos(\omega_0 + p)t + Z_3\cos(\omega_0 - p)t +\} \\ &= \mathrm{Im}\left[e^{j\Omega_0 t}\right]\cdot\left[e^{jZ_1\cos\omega_0 t}\right]\cdot\left[e^{jZ_2\cos(\omega_0+p)t}\right]\cdot \\ &\qquad \left[e^{jZ_3\cos(\omega_0-p)t}\right]\cdot\cdot\cdot\cdot \\ &= \mathrm{Im}\left[e^{j\Omega_0 t}\right]\prod_{m=0}^{\infty}\left[e^{jZ_{2m}\cos(\omega_0+mp)t}\right]\cdot \\ &\qquad \left[e^{jZ_{2m+1}\cos(\omega_0-mp)t}\right] \quad \ldots \qquad (15)\end{aligned}$$

Each product term in cosine may be expanded in a Bessel series, similar to the simple f.m. case:

$$\begin{aligned}&e^{jZ_{2m}\cos(\omega_0+mp)t} \\ &= \mathrm{J}_0(Z_{2m}) + 2[-\mathrm{J}_2(Z_{2m})\cos 2(\omega_0+mp)t \\ &\quad + \mathrm{J}_4(Z_{2m})\cos 4(\omega_0+mp)t \\ &\quad - \mathrm{J}_6(Z_{2m})\cos 6(\omega_0+mp)t + \cdots - \cdots] \\ &\quad + j2[\mathrm{J}_1(Z_{2m})\cos(\omega_0+mp)t \\ &\quad - \mathrm{J}_3(Z_{2m})\cos 3(\omega_0+mp)t \\ &\quad + \mathrm{J}_5(Z_{2m})\cos 5(\omega_0+mp)t - \cdots + \cdots] \\ &e^{jZ_{2m+1}\cos(\omega_0-mp)t} \\ &= \mathrm{J}_0(Z_{2m+1}) + 2[-\mathrm{J}_2(Z_{2m+1})\cos 2(\omega_0-mp)t \\ &\quad + \mathrm{J}_4(Z_{2m+1})\cos 4(\omega_0-mp)t \\ &\quad - \mathrm{J}_6(Z_{2m+1})\cos 6(\omega_0-mp)t + \cdots - \cdots] \\ &\quad + j2[\mathrm{J}_1(Z_{2m+1})\cos(\omega_0-mp)t \\ &\quad - \mathrm{J}_3(Z_{2m+1})\cos 3(\omega_0-mp)t \\ &\quad + \mathrm{J}_5(Z_{2m+1})\cos 5(\omega_0-mp)t - \cdots + \cdots] \qquad (16)\end{aligned}$$

With the aid of Equ. (16) expression (15) may be used to compute the frequency components of the carrier. This expression is useful despite the fact that it is an infinite product of functions, each of which is an infinite series. The series are convergent, and converge rather rapidly for practical cases. Each series may be stopped at the desired level of accuracy, which may be determined by summing the squares of terms, which in the limit is equal to unity.

Analysis of the Multichannel Case

In the case of a multichannel system, the total sub-carrier voltage modulating the carrier would be:

$$e_{sc} = e_1 + e_2 + e_3 + e_4 + \cdot \cdot \cdot \cdot + e_n \quad \ldots \qquad (17)$$

where $\qquad e_1 = \sin(\omega_1 t + M_1 \sin p_1 t)$

---

* The integral evaluated at $\tau = 0$ gives simply phase terms dependent on the modulation index, but not contributing any spectral terms.

$$e_2 = \sin(\omega_2 t + M_2 \sin p_2 t)$$

$$\begin{matrix} \cdot & \cdot \\ \cdot & \cdot \end{matrix}$$

$$e_n = \sin(\omega_n t + M_n \sin p_n t)$$

The carrier phase-angle function is then:

$$\Theta(t) = \int_0^t [\Omega_0 + 2\pi\Delta F \sum_{k=1}^{n} \sin(\omega_k\tau + M_k \sin p_k\tau)]d\tau \qquad (18)$$

When this is integrated and put into exponential form as in the single channel case, the resulting expression for the carrier is:

$$e_c = \mathrm{Im}\left[e^{j\approx_0 t}\right] \prod_{k=1}^{n} \prod_{m=0}^{\infty} \left[e^{jZ_{2m}^{k} \cos(\omega_k + mp_k)t}\right] \cdot \left[e^{jZ_{2m+1}^{k} \cos(\omega_k - mp_k)t}\right] \quad .. \quad .. \quad (19)$$

where $$Z_{2m}^{k} = \frac{-\Delta F}{f_k + mp_k/2\pi} \mathrm{J}_m(M_k)$$

$$Z_{2m+1}^{k} = \frac{-\Delta F}{f_k - mp_k/2\pi} \mathrm{J}_m(M_k)$$

k = index of kth channel

n = total number of channels

Each exponential may be expanded in Bessel series as shown in Equ. (16).

Example of Use

Expression (19) may be used to obtain close approximations of carrier sideband amplitudes by considering a finite number of sidebands of the subcarriers and limiting each series to a finite number of terms (ones of significant size). For the simplest case of a single subcarrier with a modulation index equal to unity and the carrier deviation equal to the subcarrier base frequency (a carrier modulation index of unity, if the subcarrier is unmodulated), a good approximation is obtained by considering only the first order sidebands of the subcarrier. The computation using Equ.(15) would be as follows (assuming a high intelligence frequency of $p = 0{\cdot}0825\omega_0$):

$$M = 1;\ \mathrm{J}_0(M) = 0{\cdot}765;\ \mathrm{J}_1(M) = 0{\cdot}440$$

$$\text{with } \Delta F = f_0 \text{ and } p/2\pi = 0{\cdot}0825 f_0$$

$$Z_1 = \frac{\Delta F}{f_0} \mathrm{J}_0(M) = 0{\cdot}765$$

$$Z_2 = \frac{\Delta F}{f_0 + p/2\pi} \mathrm{J}_1(M) = 0{\cdot}405$$

$$Z_3 = \frac{\Delta F}{f_0 - p/2\pi} \mathrm{J}_1(M) = 0{\cdot}470$$

For substitution in the expression[5]:

$$\mathrm{J}_0(Z_1) = 0{\cdot}859,\quad \mathrm{J}_1(Z_1) = 0{\cdot}355,\quad \mathrm{J}_2(Z_1) = 0{\cdot}069$$
$$\mathrm{J}_0(Z_2) = 0{\cdot}959,\quad \mathrm{J}_1(Z_2) = 0{\cdot}198,\quad \mathrm{J}_2(Z_2) = 0{\cdot}020$$
$$\mathrm{J}_0(Z_3) = 0{\cdot}945,\quad \mathrm{J}_1(Z_3) = 0{\cdot}229,\quad \mathrm{J}_2(Z_3) = 0{\cdot}027$$

$$\begin{aligned} e_c = \mathrm{Im}(\cos\Omega_0 t + j\sin\Omega_0 t)\ &[0{\cdot}859 + 0{\cdot}138\cos 2\omega_0 t + j0{\cdot}710 \sin\omega_0 t] \\ &[0{\cdot}959 + 0{\cdot}040\cos 2(\omega_0+p)t + j0{\cdot}396\sin(\omega_0+p)t] \\ &[0{\cdot}945 + 0{\cdot}054\cos 2(\omega_0-p)t + j0{\cdot}558\sin(\omega_0-p)t] \end{aligned}$$

This expression is expanded, taking the imaginary part and neglecting all terms that become less than 0·1 (since this means neglecting less than 1 per cent of power). The result is:

$$\begin{aligned} e_c = {} & 0{\cdot}78 \sin\Omega_0 t \\ & + 0{\cdot}32\sin(\Omega_0+\omega_0)t - 0{\cdot}32\sin(\Omega_0-\omega_0+p)t \\ & - 0{\cdot}23\sin(\Omega_0+\omega_0-p)t + 0{\cdot}23\sin(\Omega_0-\omega_0+p)t \\ & - 0{\cdot}16\sin(\Omega_0+\omega_0+p)t + 0{\cdot}16\sin(\Omega_0-\omega_0-p)t \\ & + 0{\cdot}10\sin(\Omega_0+2\omega_0-p)t - 0{\cdot}10\sin(\Omega_0 2\omega_0+p)t \end{aligned}$$

Note that the sum of the squares of these terms in this orthogonal series indicates that 99.8 per cent of the power of this term is included in this approximation.

The above expression may be compared to simple modulation of the carrier by the subcarrier unmodulated (modulation index of one).

$$\begin{aligned} e_c = {} & 0{\cdot}765\sin\Omega_0 t \\ & + 0{\cdot}440\sin(\Omega_0+\omega_0)t - 0{\cdot}440\sin(\Omega_0-\omega_0)t \\ & + 0{\cdot}120\sin(\Omega_0+2\omega_0)t + 0{\cdot}120\sin(\Omega_0-2\omega_0)t \end{aligned}$$

Neglecting terms less than 0·1 again.

Acknowledgements

The author wishes to thank Dr. F. L. Verwiebe of the Applied Physics Laboratory, The Johns Hopkins University, for his aid and suggestions on background material; and Mr. L. D. Krider of the Naval Ordnance Laboratory for checking mathematical convergence of the series expression.

REFERENCES

[1] Burrows and Decino, "Ultra Short Wave Multiplexing", *Proc. Instn Radio Engrs*, Vol. 33, pp. 84-94, 1945.

[2] J. F. Brinster, "A Survey Report on Telemetry", Applied Science Corp. of Princeton, Princeton, N.J., May 1947.

[3] Terman, "Radio Engineers' Handbook", McGraw-Hill, N.Y., 1943.

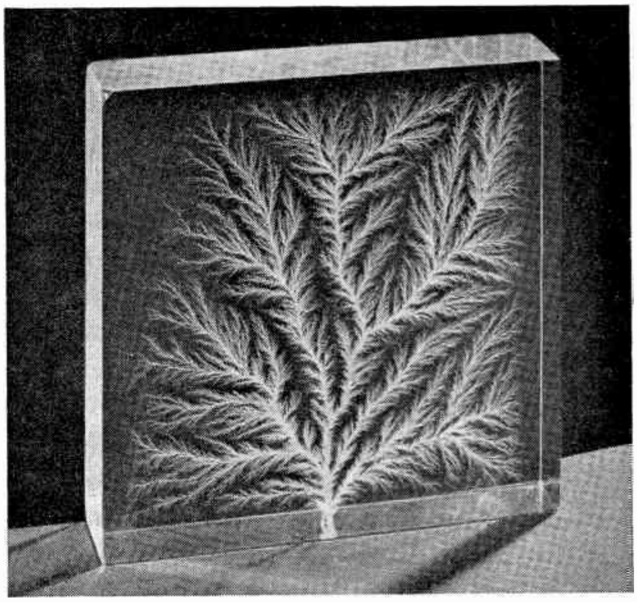
[4] McLachlan, "Bessel Functions for Engineers", The Clarendon Press, Oxford, 1934.

[5] Cambi, "Tables of Bessel Functions", Dover, N.Y., 1948.

FROZEN LIGHTNING

This tree-like pattern was produced by an electrical discharge inside a block of perspex. Electrons from a 4-MeV linear accelerator penetrated the polished surface and came to rest at a depth of about 2 cm, causing a charge to accumulate. On inserting a sharp pin into the bottom of the block, the voltage stresses were disturbed and the charge released. The insulation broke down on the passage of the resulting spark, leaving the tree effect as a permanent record of the path of the discharge.

(Courtesy Mullard Ltd.)



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.

Time-Division Multiplexing of Teleprinter Signals

SIR,—The present practice in multi-channel voice-frequency telegraphy is to use frequency-division multiplexing, each channel being either amplitude-modulated or frequency-modulated. Since time-division multiplexing is giving better performance in many fields of communication, it is worth while to study the possibilities of t.d.m. in multi-channel voice-frequency telegraphy. The general method of sampling a continuous signal of bandwidth f_c, with a short-duration pulse of repetition frequency greater than $2f_c$, is difficult to use in v.f. telegraphy in a straightforward way. The teleprinter signals are nonsynchronous and random and hence, normally, a much higher sampling-pulse repetition frequency compared to the basic frequency (50 c/s) of the teleprinter signal will be required to obtain a faithful reproduction of the signal in the receiver. In this case, however, the advantage of the small bandwidth requirement of frequency-division multiplexing of telegraph signals is lost.

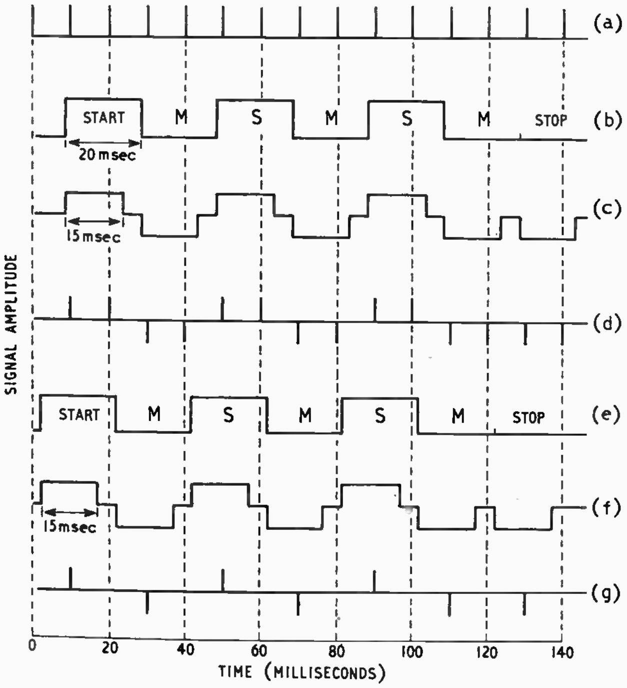


Fig. 1. *Single or pair of pulses for each signal element; (a) channel sampling pulses, (b) teleprinter signal for letter 'y', (c) reshaped 15-msec pulses, (d) modulator output: a pair of pulses for each element, (e) another teleprinter signal with different phase, (f) 15-msec reshaped pulse for (e), (g) modulator output: a single pulse for each element*

To minimize the bandwidth required, if each space/mark signal is designated by a single short-duration pulse spaced 20 msec from adjacent pulses (20 msec is the width of each element of a teleprinter signal), then there is a chance that any element whose width is smaller than 20 msec, owing to some distortion either in the teleprinter or in the line, may be missed by the sampling pulse. On the other hand, if short sampling pulses spaced 10 msec apart are used, then again there is a possibility that some elements will cover three sampling pulses and some only one. Thus the output will have 50% distortion. It is therefore necessary that the input signal to the t.d.m. be accurately timed.

The present scheme is to use a circuit, similar to that of an electronic regenerative repeater[1], to convert the distorted incoming teleprinter signal into elements of accurate duration equal to anything between 11 to 19 msec (say 15 msec). The corrected signal is now scanned by narrow pulses spaced 10 msec apart, and the resultant output consists of either two pulses per element or one pulse per element, depending upon the relative phase difference between the sampling pulses and the start pulses of the teleprinter signal. The two possibilities are shown in Fig. 1. In the receiver, these narrow pulses are fed to a modified bistable multivibrator[2] to reproduce the 20-msec signal elements.

An experimental circuit on the above principle has been set up to study the various problems involved. Fig. 2 is the block schematic of the circuit. Fig. 3 shows the waveforms at different stages of the sender and the receiver. The incoming teleprinter signal is reshaped to 15-msec pulses in the converter, which consists of a scanner and two monostable multivibrators. The channel modulator is a two-way

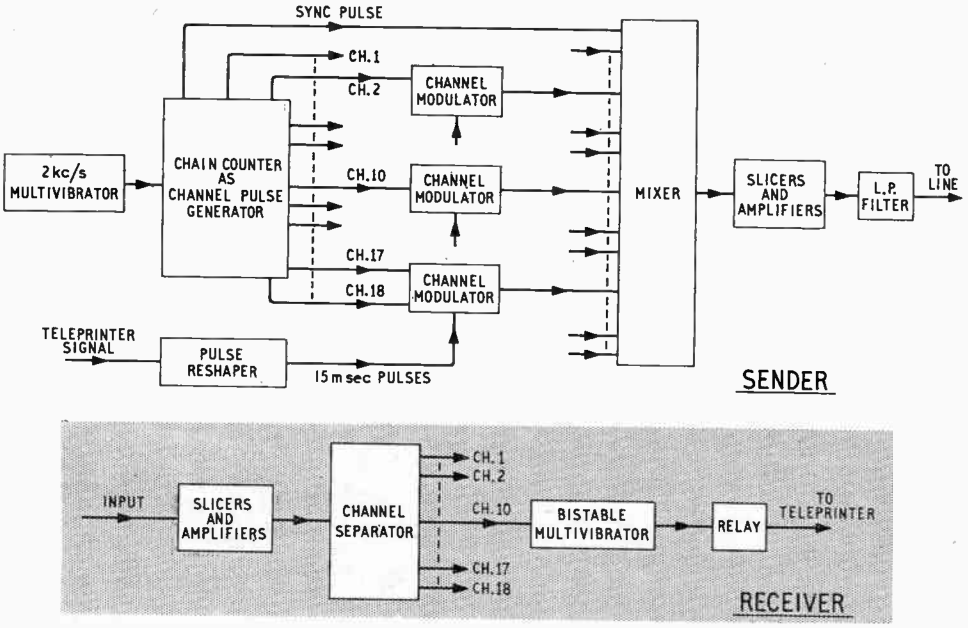


Fig. 2. *Block schematic of sender-receiver*

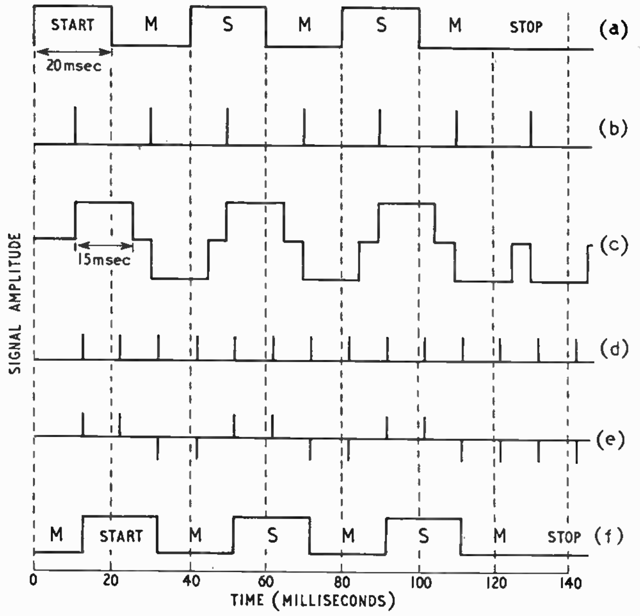


Fig. 3. *Waveforms of the sender and receiver; Sender signals: (a) teleprinter signal for letter 'y', (b) scanning pulses in the signal shaper, (c) output of multivibrator: reshaped pulses, (d) channel modulator sampling pulses, (e) channel modulator output and input to receiver. Receiver signal: (f) output of bistable multivibrator in the receiver, equivalent to 'y' but delayed by* 12 *msec*

gate circuit, which passes positive pulses in response to space signals and negative pulses in response to mark signals. In the receiver, the channels are separated and each channel signal is fed to a modified bistable multivibrator. The multivibrator is triggered to one stable condition by the negative pulses and to the other stable condition by the positive pulses. A relay controlled by the multivibrator sends space-mark signals to the receiving teleprinter. Alternatively, the send modulator may be a simple gate which passes only positive pulses in response to space signals, no pulse being sent during the mark condition. In the receiver, the positive pulses trigger a monostable multivibrator with output pulses of duration slightly less than 20 msec, and the relay is biased to give the mark signal when no pulses are received.

With an available bandwidth of 4 kc/s, 18 channels can be accommodated with sampling pulses of duration equal to 0·25 msec and 10-msec spacing. The synchronizing pulse may be of 0·75 msec duration. Using slicers at the input of the receiver, a considerable improvement in the output signal-to-noise ratio[3] will be obtained at the threshold point of 6-dB input signal-to-noise ratio. Since both the space and mark signals produce pulses, either positive or negative, the interference due to noise pulses which occurs during the no-tone condition in a normal voice-frequency system will be almost eliminated.

It is found, however, that owing to the restricted bandwidth of the system, there are possibilities of minor pulses being generated in the modulator, when a triangular sampling pulse partially overlaps a trapezoidal space-mark pulse. To eliminate these spurious pulses from the output, the mixer output is passed through slicers and limiting amplifiers before being fed to the line. This system promises a better performance than voice-frequency telegraphy with respect to signal-to-noise ratio, distortion, and fading, and eliminates the use of complicated filters.

The author records his thanks to Prof. H. Rakshit, D.Sc., F.N.I., for his kind interest in the work.

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REFERENCES

[1] R. O. Carter, L. K. Wheeler and A. C. Frost, "An Electronic Regenerative Repeater for 7½ unit Start-Stop Telegraph Signals", *P.O. Elect. Engrs J.*, 1949, Vol. 41, pp. 222-227.

[2] B. Chance, W. Hughes, *et al*, "Waveforms", Radiation Laboratory Series, Vol. 19. McGraw-Hill (1949).

[3] J. Das, "Quantitative Noise Reduction in Pulse Time Modulation", *Electronic Engng*, 1955, Vol. 27, pp. 406-409.

New Books

Fundamental Principles of Transistors

By J. Evans, B.Sc., Ph.D., A.K.C. Pp. 255 + xii. Heywood & Co. Ltd., Southampton Street, London, W.C.2. Price 45s.

There has been for a long time a need for a book which explains the action of semiconducting devices in a manner comprehensible to the electronic engineer as distinct from the physicist. An adequate understanding without some knowledge of relevant physics is naturally impossible. But, hitherto, treatments have in the main been either so simple as to be valueless or so complex that they are unintelligible.

The author of this book is to be congratulated on steering a middle course which has resulted in his producing the best account of transistor action which the reviewer has encountered. He starts with a chapter, Basic Theory of Semiconductors, in which the nature and need for single crystals are described; energy bands, the hole concept, impurity semiconductors, activation, compensation, mobility, conductivity and traps are among the other important matters which are briefly, but clearly, discussed.

The measurement of semiconductor parameters occupies the next chapter and the book then turns to the theory of the p-n junction, which is the theory of the semiconductor diode, and then there is a chapter on the preparation of such junctions.

Junction transistors are next treated. This chapter is not confined to the usual 'triode' transistor, but covers also the p-n hook collector, the drift transistor and avalanche multiplication. This is followed by a chapter on point-contact transistors, after which the measurement of transistor parameters is treated and then transistor manufacture. The last two chapters cover special types and silicon and other materials. There are appendixes on the teaching of transistor physics, in which various experiments are described, on the parameters of some commercial transistors, and on the identification of mixed impurities.

No attempt is made to deal in any way with transistor circuitry, but the usual equivalent circuits for the transistor are given. Throughout the book, the argument and explanations are given quite largely in words and do not depend greatly on mathematics. The equations used are nearly all of an elementary kind and few should cause even those engineers who dislike mathematics to pause in their reading.

The book is an excellent one which can be recommended to all in any way interested in how semiconducting devices work.

W.T.C.

Semiconductors: Their Theory and Practice

By G. Goudet and C. Meuleau. Pp. 316 + xviii. Macdonald & Evans Ltd., 8 John Street, Bedford Row, London, W.C.1. Price 105s.

The title "Semiconductors" covers a very wide field but this book, which is divided into three main parts, is clearly intended for the telecommunications engineer. The first part deals with general fundamental theories, the second with the technology of semiconductors and the third with the principal applications of semiconductors, thermistors and varistors.

In the first part, the necessity of quantum mechanics in the study of the solid state is emphasized, it being pointed out for example that classical mechanics can predict a Hall effect in the opposite direction to that which is observed. The fundamental idea of a 'hole' can also only be justified by quantum mechanics. The introduction of just so much of this rather difficult subject as is necessary for the purpose in hand is well done.

By means of the basic theory developed in the first two chapters, the band theory of semiconductors is discussed in Chapter 3, leading to the concept of permitted and forbidden bands and to conduction by means of 'holes' as well as by free electrons. Fermi-Dirac statistics are then introduced and the idea of the Fermi-level and pseudo Fermi-levels explained.

This first part concludes with a discussion of the mechanism of current conduction in solids, graduating from the formulation of the physical basis for Ohm's Law to the important part that diffusion plays in heterogeneous material, to which class nearly all semiconductor arrangements belong.

The second part is the shortest and deals with the properties of single crystals, their preparation and with physical measurements used in research. There is no attempt to deal exhaustively with these topics, but physical and chemical imperfections, intermetallic compounds and oxide semiconductors are among those discussed as is also the preparation of crystals by zone melting. Where items are treated less fully, reference is made to appropriate literature. In fact a feature of this book is that, in the second and third parts, a bibliography is grouped at the end of each chapter, a total of well over 300 references, some as recent as the middle of 1955, being cited.

The third part deals mainly with both the theoretical and practical aspects of crystal diodes, triodes and tetrodes. The reader is well equipped by the first part to appreciate the discussion on the theoretical behaviour of both abrupt and graded junctions and of metal to semiconductor contacts. This leads naturally to an examination of the behaviour of both point-contact and junction transistors. The theoretical calculation of such important parameters as current gain and cut-off frequency is carried out and the properties and practical limitations of transistors produced by pulling, alloying and diffusion techniques are investigated.

The authors are in fact careful to draw attention to, and explain, departures from the theoretical behaviour in practical devices and this considerably enhances the value of this book to engineers.

Equivalent circuits for both low and high frequencies are briefly considered but, as with other topics which are not fully treated, adequate references to well-known papers are made.

Finally, there is a chapter on other semiconductor devices such as the photo-transistor and the solar battery and on some applications of the Hall effect.

The original book was written in French but the translation is of such a high standard, that at no time is the reader aware of this. Two minor features which appeal to the reviewer are the outlining of all important formulae and the indication at the corner of each page of the chapter, section and sub-section, which greatly facilitate the reference from one part of the book to another.

The authors are to be congratulated on producing a book which holds the balance between the theoretical and practical aspects of this fascinating subject and which should therefore appeal to telecommunications engineers who desire to obtain a deeper understanding of the semiconductor devices which they are using.

G.H.P.

Dry Battery Receivers

By E. Rodenhuis. Pp. 240. Philips Technical Library, distributed in Great Britain by Cleaver Hume Press Ltd., 31 Wright's Lane, London, W.8. Price 32s. 6d.

Data relating to valves for dry-battery receivers, and examples of circuit design.

Magnetic Amplifier Circuits

By W. A. Geyger. Pp. 394. McGraw-Hill Publishing Co. Ltd., 95 Farringdon Street, London, E.C.4. Price 52s. 6d.

A second edition of the author's well-known work, revised and enlarged.

Semiconductor Abstracts, Vol. III

Edited by E. Paskell. Pp. 322. Compiled by Battelle Memorial Institute. Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price 80s.

1,258 useful abstracts, with author and subject indexes. The abstracts are classified according to the nature of the semiconducting material, and there is one section on the theory of semiconductors. Metallic oxides are included as well as the materials of more recent interest.

Basic Mathematics for Radio and Electronics. 3rd Edn.

By F. M. Colebrook, B.Sc., D.I.C., A.C.G.I., and J. W. Head, M.A.(Cantab). Pp. 359. Published for *Wireless World* by Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price 17s. 6d.

A revised and enlarged edition of the late F. M. Colebrook's "Basic Mathematics for Radio Students". The original material has been retained and there are two additional chapters by J. W. Head, one on Heaviside's operational technique and one entitled "Miscellaneous Techniques", which covers matrix algebra, linear differential equations, how to simplify numerical computation by labour-saving tricks, and fitting straight-line equations to data by the least-squares method.

Iliffe Publications

It is suggested that the following publications are suitable for Christmas presents:

Correcting Television Picture Faults

By John Cura and Leonard Stanley. Price 3s. 6d. (by post 3s. 9d.).

Improve Your Television Reception

By John Cura and Leonard Stanley. Price 5s. (by post 5s. 4d.).

"Wireless World" Diary 1958

Published by T. J. & J. Smith in conjunction with *Wireless World*. Pp. 80 of reference material, plus diary pages of a week to an opening. Price: Leather 6s. 3d.; Rexine 4s. 6d. Postage 4d. Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1.

Contents include: Abacs, Abbreviations, Addresses of Radio Organizations, Aerials, Amateur Transmission, B.A. Screws and Drill Sizes, Binary Code, Circuit Diagrams, Coil-Winding Data, Component Coding, Conversion Table, Decibel Equivalents, Graphical Design Data, Electrical and Magnetic Units, Useful Formulae, Frequency Allocations, Greek Alphabet, Electrical Interference, Licence Regulations, M.K.S. and C.G.S. Units, Mathematical Signs, Resistance of Metals, Modulation Classification, Morse Code, Resistor and Capacitor Markings, Resistor Ratings, Resistors in Parallel, Standard Frequencies, Graphical and Letter Symbols, Television Attenuators and Splitting Circuits, Television Channels, Unit Abbreviations, V.H.F. Broadcasting, Valve Base Connections, Waveband Classification, Weights and Measures, Wire and Wood Screw Tables.

STANDARD-FREQUENCY TRANSMISSIONS

(Communication from the National Physical Laboratory)

Deviations from nominal frequency for October* 1957

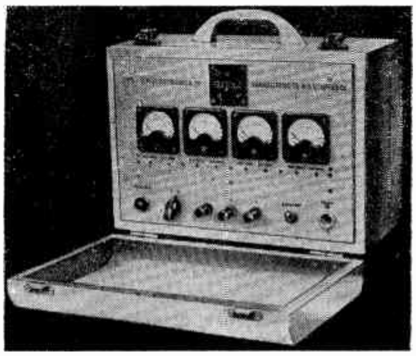
Date 1957 October	MSF 60 kc/s 2030 G.M.T. parts in 10^9	Droitwich 200 kc/s 1030 G.M.T. parts in 10^8
1	+ 1	+ 3
2	+ 1	+ 3
3	+ 1	+ 2
4	+ 1	+ 2
5	+ 1	N.M.
6	+ 1	+ 2
7	+ 1	+ 2
8	+ 1	+ 2
9	+ 1	N.M.
10	+ 1	+ 3
11	+ 1	+ 3
12	N.M.	N.M.
13	N.M.	+ 3
14	+ 1	+ 4
15	+ 2	+ 5
16	+ 2	− 2
17	+ 2	− 2
18	+ 2	− 2
19	+ 2	− 1
20	+ 2	− 1
21	+ 2	− 1
22	+ 2	− 1
23	+ 2	0
24	+ 2	− 1
25	+ 2	− 1
26	+ 2	− 1
27	+ 3	0
28	+ 3	− 1
29	+ 2	− 1
30	+ 2	0
31	+ 3	0

* *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

Millisecond Stopclock

The Venner millisecond stopclock Type TSA4 covers the range from 0·1 msec to 27·8 hours. The instrument is constructed from nine transistorized units. The basic time reference is a transistor crystal oscillator operating at a frequency of 10 kc/s. Pulses from the oscillator are passed via a gate to four transistor decade counters, and then to a cycle counter. The division ratio provided by the four decades is 10,000 and the cycle counter receives one pulse per second. Decimal fractions of a second are read from four meters calibrated 0–9.



The gating is arranged so that the closed or open times of contacts can be measured, or the time between one pair of contacts opening or closing and another pair opening or closing. Alternatively, a positive pulse can be used to start or stop the instrument.

Forty-six transistors are employed, but the consumption is only 1 W at 12 V. The instrument case measures 13 in. by 9 in. by 7½ in. A battery-carrying case is available, and a transistor stabilized power supply can be used for mains operation.

Venner Electronics Ltd.,
Kingston By-Pass, New Malden, Surrey.

High-Sensitivity 5 in. Cathode-Ray Tube

A new instrument cathode-ray tube, the 5BHP, which combines high deflection sensitivity with low distortion and uses a helical post-deflection accelerator system, has been developed by the M.O. Valve Co. Ltd. (a subsidiary of the G.E.C.). Intended primarily for use in wide-band measuring oscilloscopes, the 5 in.-diameter flat-face tube is stated to have a Y-plate deflection sensitivity of 1·5 mm per volt under typical conditions. The tube has an aluminized screen.

A conventional post-deflection accelerator consists of a conducting band applied to the inside of the tube near the screen to which a voltage up to double that of the electron gun may be applied. Such a tube operating with a p.d.a. voltage of 10 kV would, therefore, have a gun voltage of about 5 kV. If the ratio of p.d.a. to gun voltage is increased beyond 2 : 1, distortion of the trace is produced in the electrostatic lens formed between the p.d.a. band and the rest of the tube.

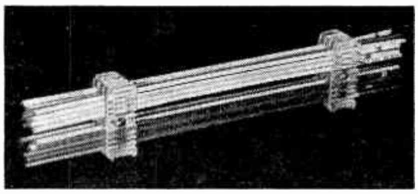
In the case of a helical p.d.a., however, its effect is distributed over the whole length of the helix and the distortion is very considerably reduced. This enables the p.d.a. ratio to be increased to 6 : 1, under which condition the electron gun operates at only 1·67 kV if the p.d.a. voltage is 10 kV. Since the deflection sensitivity is inversely proportional to the gun voltage, a helical p.d.a. tube is three times as sensitive as the tube with conventional p.d.a.

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

Cable Clip

A new form of cable clip is now being marketed by Creators Ltd. This clip, which is called the 'Huckepack', consists of interlocking plastic mouldings, which can be built up to a depth of 10 layers and fastened to a baseboard or chassis by a single bolt.

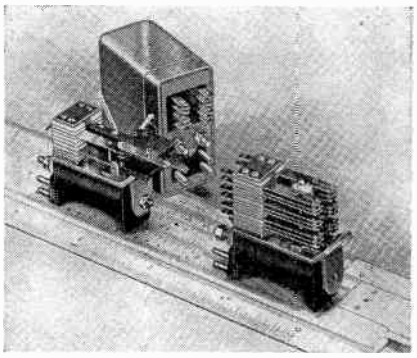
The clips are available in four sizes to suit different types of cable. Apart from the advantage of rapid and easy assembly of cable forms, these clips allow a very large number of cables to be carried in a very small space.



A further advantage claimed is that the cable layout can be quickly changed if required and cables can easily be traced without the use of conventional identification systems.

Creators Ltd.,
Plansel Works, Sheerwater, Woking, Surrey.

Subminiature Relay



An improved subminiature relay type P3, Mark 2, has been developed, and can be supplied with up to six change-over contacts or with two special low-capacitance change-over contacts for high-frequency circuits. It is stated that operation at temperatures up to 100°C is permissible, that a shock-proof armature mounting is employed and that the relay can be mounted through a chassis or on to a printed circuit.

Points from the makers' specification are: coil resistance up to 9,000 Ω (double-wound and slugged coils are available); consumption 100 mW minimum; typical contact ratings 25 V d.c., 2 A; 250 V a.c., 1 A. The capacitance between open contacts of the low-capacitance version is < 1 pF. Relays can be supplied with dust covers or hermetically sealed.

D. Robinson & Company,
58 Oaks Avenue, Worcester Park, Surrey.

1,000-Mc/s Valve Voltmeter

Marconi Instruments Ltd. have developed a new valve voltmeter, type TF1041A, which is claimed to be the first British instrument of its kind with a frequency range extending to 1,000 Mc/s.

For a.c. measurement, the frequency range is given as 20 c/s to 1,000 Mc/s; input capacitance 1·5 pF and input resistance 0·5 MΩ at 10 Mc/s and 150 kΩ at 100 Mc/s; the voltage range is 0·05 to 300 volts. D.C. voltages up to 1,000 volts can be measured at an input impedance of

40 MΩ balanced and 20 MΩ unbalanced. As an ohmmeter, the instrument measures resistance from 0·2 ohm to 500 MΩ.

The a.c. probe unit contains a disc-seal diode rectifier with a resonant frequency of 3,000 Mc/s, low interelectrode capacitance and short transit time.

Marconi Instruments Ltd.,
St. Albans, Herts.

'Fluon' Spray-Coating Dispersions

Imperial Chemical Industries Ltd., Plastics Division, have now added a number of spray-coating dispersions to their 'Fluon' p.t.f.e. range. P.t.f.e. is claimed to be the best non-stick material; coefficients of static and dynamic friction are equal and about the same as wet ice on wet ice.

The dispersions can be applied by spraying, dipping or brushing to a wide variety of materials, such as metal, glass and ceramics. The uses for the coatings include low-friction coatings for mechanical cables and non-wetting surfaces for ceramic insulators.

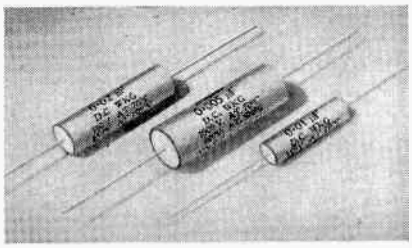
Imperial Chemical Industries Ltd.,
*Imperial Chemical House, Millbank, London, S.W.*1.

Paper Tubular Capacitors

T.C.C. have introduced a new range of insulated capacitors to comply with the requirements of Inter-Services Specification R.C.S. 131, 40/100 H.I., and conforming to sizes in R.C.L. 131 (CP.31 style), being suitable for working at −40° to +100°C.

These are stated to be of foil and paper dielectric, non-inductively wound and impregnated with 'Visconol-X' compound which improves the performance of paper insulation by inhibiting ionization and checking the fall in insulation resistance following temperature rises.

The elements are housed in epoxy-phenolic resin-bonded fibre-glass, a very high-grade insulating material, with end-seals of a special resin said to afford complete protection against the ingress of moisture in service.



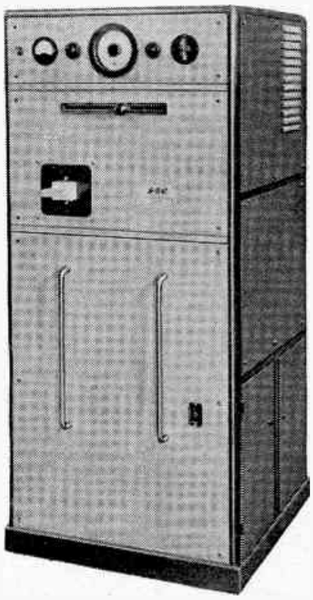
Capacitors are available with rated working voltages at 70°C of 200, 350, 500, 750 and 1,000 V.

The Telegraph Condenser Co. Ltd.,
*Radio Division, North Acton, London, W.*3

18-kW H.F. Induction Heater

A new 18-kW high-frequency induction heater made by G.E.C. occupies less than 11 sq. ft. of floor space but is said to provide sufficient power for surface-hardening applications and for brazing heavy sections. It has a power output control which adjusts the impedance matching of the load by varying the coupling between the tank coil and the concentrator to which the heating coils are attached.

Power input is approximately 36 kW at full load with a power output of 18 kW. The valves used are a BR1102 oscillator valve and six GU21 mercury-vapour rectifier valves in a full-wave circuit. The frequency of the unit is approximately 500 kc/s. An anode-current meter indicates the output power and an hour meter records valve life.



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

Anti-Rust Device

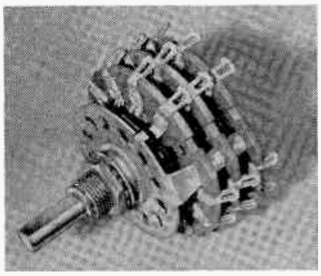
Paper coated with a special chemical which emits vapour which prevents rust and corrosion is now available. It is claimed to be effective even when oxygen and water vapour are present together. The paper, which is known as Stace V.P.I. paper, need not be in contact with the surface to be protected, and remains effective at a distance of 12 in.

Leonard Stace Ltd.,
Gloucester Road, Cheltenham, Glos.

New Rotary Switch

The latest addition to the N.S.F. range of 'Oak' rotary switches, model DQH, incorporates an improved notched stator, and is available with one, two or three sections. The advantage claimed for the notched stator is that it eliminates trouble due to loosening of contact clips as a result of overheating during the soldering operation.

Model DQH is made with a 30° throw only, and the following maximum contact combinations are available: 1-pole, 2–12 positions; 2-poles, 2–6 positions; 3-poles, 2–4 positions; 4-poles, 2 or 3 positions; 5-poles, on–off; 6-poles, on–off.



N.S.F. Ltd.,
31–32 *Alfred Place, London, W.C.*1.

Watertight Cable Joints

A new method of providing watertight insulated joints in multicore cables has been introduced by Egerton Engineering in their new cable jointer. The cable conductors are joined together in any orthodox manner and then a preformed polythene sleeve is inserted between the various cores. The cable to be joined is then placed in a small mould and is injected with polythene from a hand-operated portable injection moulder. A typical joint shown inset below.

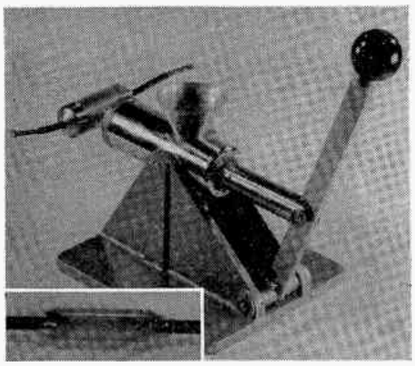
The makers state that samples of joints finished by this process have been tested in humidity chambers, the result being that a 3-core rubber-covered cable withstood 2,000 V for 29 hours in extreme humidity. This particular cable was then subjected to 17,000 volts, by which time the rubber insulation broke down and left the joint intact.

By using different moulds, plastic sleeves can be formed over a cable at junctions with small plugs and sockets, such as coaxial plugs, etc. This greatly increases the strength of the cable where it is normally very weak.

The machine shown weighs about 9 lb. and has been designed to accommodate all cable from $\frac{3}{16}$ in. to $\frac{1}{2}$ in. diameter and from 1 to 12 cores, and its power loading is only 100 W.

For smaller and single-core cables a pistol type of jointer has been developed.

Egerton Engineering,
5 *Nightingale Road, Petts Wood, 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 publisher concerned.*

ACOUSTICS AND AUDIO FREQUENCIES

534.121.1 **3721**

The Calculation of the Resonance Frequencies of Radially Oscillating Circular Disks and Rings.—E. Tränkle. (*Frequenz*, May 1957, Vol. 11, No. 5, pp. 142–145.)

534.2-14 **3722**

Sound Diffraction at a Thin Bounded Elastic Cylindrical Shell.—L. M. Lyamshev. (*C. R. Acad. Sci. U.R.S.S.*, 11th July 1957, Vol. 115, No. 2, pp. 271–273. In Russian.) Brief mathematical analysis. See also 309 of 1956.

534.24 **3723**

Reflection of Plane Waves of Sound from a Sinusoidal Surface.—H. S. Heaps. (*J. appl. Phys.*, July 1957, Vol. 28, No. 7, pp. 815–818.) The amplitudes of the reflected plane, undamped waves are calculated for the least mean square value of the surface pressure. Good agreement is obtained with the values measured by LaCasce and Tamarkin (1938 of 1956).

534.76 **3724**

Experimental Investigations of Monaural Acoustic Localization.—A. Manfredi, L. Fiori-Ratti & S. Crifò. (*Ricerca sci.*, April 1957, Vol. 27, No. 4, pp. 1155–1160.) Test results indicate the existence in the human ear of a faculty of auditory perspective, particularly for noises of short duration and high harmonic content.

621.395.61 **3725**

On the Phasing of Microphones.—B. B. Bauer. (*Trans. Inst. Radio Engrs*, Nov./Dec. 1956, Vol. AU-4, No. 6, pp. 155–161. Abstract, *Proc. Inst. Radio Engrs*, April 1957, Vol. 45, No. 4, pp. 571–572.)

621.395.623.7 **3726**

Loudspeakers in Parallel.—J. Moir. (*Wireless World*, Oct. 1957, Vol. 63, No. 10, pp. 479–481.) No increase in source size is obtained but advantages exist including lower distortion and increased efficiency.

621.395.623.742 : 621.375.2.029.3 **3727**

Amplifiers with Directly Coupled Loudspeakers.—J. Rodrigues de Miranda. (*Tijdschr. ned. Radiogenoot.*, Jan. 1957, Vol. 22, No. 1, pp. 15–27.) Description of an electrodynamic loudspeaker with 800-Ω speech coil wound with wire of 40 μ diameter. A response essentially flat between 20 c/s and 100 kc/s is obtained using a pre-amplifier and a single-ended push-pull amplifier without output transformer. Circuit and characteristics are shown.

621.395.625.3 **3728**

On the Resolving Power in the Process of Magnetic Recording.—S. Duinker. (*Tijdschr. ned. Radiogenoot.*, Jan. 1957, Vol. 22, No. 1, pp. 29–48. In English.) Universal field curves are derived for various distances from a recording head of two semi-infinite pole pieces of infinite permeability, and lines of equal field strength are obtained for the resultant field. The recording process is analysed for the case of a pulse superimposed on a steady d.c., with and without a.c. bias. Resolution, defined in terms of a limiting wavelength, depends on the shape of the field curve and depth of magnetization; with a.c. bias the relative strength of the biasing field and the critical field strength for the tape are also important. Without a.c. bias resolution of the order of the gap length is obtainable; with bias a much shorter wavelength can be recorded.

621.395.625.3 : 621.397.5 **3729**

Video Tape Recorder uses Revolving Heads.—Snyder. (See 4018.)

AERIALS AND TRANSMISSION LINES

621.372.2 **3730**

A Graphical Approach to the Study of Irregularities in Transmission Lines.—W. T. Blackband. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 433–438.)

621.372.2 **3731**

Resonance in Two Coupled Sections of a Line with Low Losses.—N. S. Kochanov. (*Radiotekhnika, Moscow*, July 1956, Vol. 11, No. 7, pp. 60–62.) Brief mathematical analysis.

621.372.2 : 621.372.8 **3732**

A New Type of Surface Waveguide with Bandpass Properties.—D. Marcuse. (*Arch. elekt. Übertragung*, April, 1957, Vol. 11, No. 4, pp. 146–148.) An axially stacked waveguide is described which consists of thin circular metal disks alternating with disks of dielectric material. Transmission of surface waves only takes place in certain frequency bands. Some transmission constants are calculated.

621.372.2 : 621.372.8 **3733**

Double-Slab Arbitrary-Polarization Surface-Wave Structure.—R. E. Plummer & R. C. Hansen. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 465–471.) An analysis of the double-layer dielectric slab on a perfectly conducting surface. Conditions permitting the propagation of a wave of arbitrary polarization are derived.

621.372.2 : 621.372.8 **3734**

A Note on the Excitation of Surface Waves.—A. L. Cullen. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 472–474.) An extension of results on the launching efficiency obtained in a previous paper (22 of 1955).

621.372.2.011.2 **3735**

The Characteristic Impedance of a Slotted Coaxial Line.—R. E. Collin. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. MTT-4, No. 1, pp. 4–8. Abstract, *Proc. Inst. Radio Engrs*, April 1956, Vol. 44, No. 4, p. 581.)

621.372.8 **3736**

Waveguide Characteristics.—A. E. Karbowiak. (*Electronic Radio Engr*, Oct. 1957, Vol. 34, No. 10, pp. 379–387.) Application of the surface impedance approach to the analysis of wave propagation in parallel-plane, rectangular and circular waveguides leads to a general expression for the propagation coefficient, which holds above and below as well as at the cut-off frequency. Numerical examples are given.

621.372.8 **3737**

Analysis of Some Types of Septate Waveguides.—R. G. Mirimanov & G. I. Zhileĭko. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 172–183.) Six types of waveguides are considered and their main characteristics tabulated.

621.372.8 **3738**

Propagation of Transients in Waveguides.—A. E. Karbowiak. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 339–348.) Basic theory is developed and applied to the propagation of a unit-step-modulated carrier and of pulses. Formulae and graphs are outlined and numerical examples given.

621.372.8 **3739**

Mode Separation at the Π Mode in a Dielectric-Loaded Waveguide Cavity.—G. B. Walker & N. D. West. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 381–387.) A finite group-velocity at the Π-mode frequency can be obtained in a waveguide loaded with solid dielectric disks which are reflectionless at the required frequency. Central holes required in the disks to permit passage of an electron beam set up evanescent and other propagating modes but operation is still possible in the Π mode.

621.372.8 **3740**

A Contribution to the Design of Multi-element Directional Couplers.—J. W. Crompton. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 398–402.) Analysis of a cascaded set of 2-element couplers emphasizes physical principles and enables the coupling factors and dimensional tolerances of elements to be easily calculated.

621.372.8 **3741**

Calculation of Symmetrical Junctions in Waveguides of Circular Section for Waves of the H_{0n} Type.—Yu. N. Kazantsev. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 150–156.) The reflection coefficient is derived for several forms of dielectric insert and also for a conical metal coupling between two circular waveguides. The dielectric load is calculated which has a small reflection coefficient for the H_{01} mode.

621.372.8 **3742**

Waveguide Power Dividers.—T. G. Hame. (*Electronic Engng*, Aug. 1957, Vol. 29, No. 354, pp. 368–373.) New forms of T and Y junctions incorporating wide-band matching wedges or mitres.

621.372.8 : 538.6 **3743**

Gyromagnetic Excitation of a Waveguide.—V. V. Nikol'ski. (*Radiotekhnika i Elekronika*, Feb. 1957, Vol. 2, No. 2, pp. 157–171.) The formula for the gyromagnetic excitation of a waveguide is generalized for any direction of a constant magnetic field. The use of ferrite slabs or rods magnetized in different planes in rectangular or cylindrical waveguides or in coaxial lines is described.

621.372.8 : 621.318.134 **3744**

Broad-Band Ferrite Microwave Isolator.—P. H. Vartanian, J. L. Melchor & W. P. Ayres. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. MTT-4, No. 1, pp. 8–13. Abstract, *Proc. Inst. Radio Engrs*, April 1956, Vol. 44, No. 4, p. 581.)

621.372.8 : 621.318.134 : 621.372.5 **3745**

The Gyrator.—Roddam. (See 3769.)

621.396.67.029.62 : 621.3.012.12 **3746**

Distortion of a Polar Diagram due to Interposition of Wooden Screen in the Vicinity of a V.H.F. Radiator.—H. R. B. Seetharam & M. N. Gadre. (*J. Instn Telecommun. Engrs, India*, March 1957, Vol. 3, No. 2, pp. 140–156.) A theoretical and experimental study for different forms, coatings and humidity.

621.396.677.75 **3747**

A Method of Estimating the Power Radiated Directly at the Feed of a Dielectric-Rod Aerial.—R. H. Clarke. (*Proc. Instn elect. Engrs*, Part B, Sept. 1957, Vol. 104, No. 17, pp. 511–514.) The method is based on a simple transmission-line analogue. As an example the radiation system at 3 cm λ of a waveguide-fed rod of rectangular cross-section is found.

621.396.677.8 **3748**

A Method of Raising the Efficiency of Simple Wide-Band Aerials.—S. I. Nadenenko. (*Radiotekhnika, Moscow*, Aug. 1956, Vol. 11, No. 8, pp. 25–30.) The efficiency of the symmetrical dipole is increased by a plane reflector consisting of conductors parallel to the dipole and supported by the same masts.

621.396.677.8 : 523.16 **3749**

New Radio Telescope.—(*Wireless World*, Oct. 1957, Vol. 63, No. 10, pp. 477–478.) A brief description of the aperture synthesis technique to be used with the aerial system of the radio astronomy observatory at Cambridge, England.

621.396.677.833 : 523.16 **3750**

The Jodrell Bank Radio Telescope.—Lovell. (See 3847.)

621.396.677.85 **3751**

Recent Research on Microwave Optical Systems.—N. Carrara, L. Ronchi, M. Schaffner & G. Toraldo di Francia. (*Alta Frequenza*, April/June 1957, Vol. 26, Nos. 2/3, pp. 116–158.) Survey of work carried out between 1953 and 1955 at the ' Centre for Studies in Microwave Physics ' in Florence. Some lenses of configuration type are described, including the ' Toraldo ' lens which is suitable for the rapid scanning of large angles. Methods of aberration correction and the development of microwave lens systems analogous to thick optical lenses are discussed.

AUTOMATIC COMPUTERS

681.142 **3752**

Progress in Automatic Computers, 1956.—A. Walther & W. Hoffman. (*Z. Ver. dtsch. Ing.*, 1st June 1957, Vol. 99, No. 16, pp. 731–737.) Brief survey with 198 references.

681.142 **3753**

The Design of the Ferranti Pegasus Computer: Part 1.—T. G. H. Braunholtz. (*Electronic Engng*, Aug. 1957, Vol. 29, No. 354, pp. 358–363.) A record of some of the considerations from which the design was developed.

681.142 **3754**

The Random-Access Memory Accounting Machine.—(*IBM J. Res. Developm.*, Jan. 1957, Vol. 1, No. 1, pp. 62–71 & 72–75.)

Part 1—System Organization of the IBM 305.—M. L. Lesser & J. W. Haanstra.

Part 2—The Magnetic-Disk, Random-Access Memory.—T. Noyes & W. E. Dickinson.

681.142 **3755**

Machine for Solving Polynomial Equations of Higher Degree.—G. C. Brack. (*Elektronische Rundschau*, June 1957, Vol. 11, No. 6, pp. 183–187.) The method applies to equations with complex coefficients of theoretically any degree. The apparatus described is compact and can be used for solving equations of the fifth degree ;

solutions are indicated on a valve voltmeter and c.r.o. Operation is illustrated by examples.

681.142 **3756**

High-Speed Analogue-to-Digital Converters.—G. J. Herring & D. Lamb. (*J. Brit. Instn Radio Engrs*, Aug. 1957, Vol. 17, No. 8, pp. 407–420.) A summary of general principles in the conversion of voltages from analogue computers into digital form, for subsequent processing, and detailed circuits of one such converter. 100-kc/s pulses are controlled by gates operated by the input voltages in a servo-type circuit.

681.142 **3757**

Two New Comparison Instructions for a Three-Address Electronic Digital Computer.—L. Dadda. (*Ricerca sci.*, April 1957, Vol. 27, No. 4, pp. 1125–1132.) Description of a programming system based on a particular criterion for comparing binary numbers.

681.142 **3758**

A Control Circuit for Magnetic-Drum Storage Systems in Electronic Computers.—L. Dadda. (*Ricerca sci.*, May 1957, Vol. 27, No. 5, pp. 1482–1488.) The circuit described is used for checking binary number read-out for a particular storage system.

681.142 **3759**

Digital Compensation for Control and Simulation.—J. Tou. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1243–1248.) A technique is described for improving the performance of digital feedback control systems and operational digital simulators by making use of the computer to perform information programming or data processing.

681.142 : 621-5 **3760**

Integration of Computers with Factory Processes.—A. H. Cooper. (*J. Brit. Instn Radio Engrs*, Aug. 1957, Vol. 17, No. 8, pp. 431–440.)

681.142 : 621.3.049.75 **3761**

A Three-Dimensional Printed Back Panel.—E. R. Wyma. (*IBM J. Res. Developm.*, Jan. 1957, Vol. 1, No. 1, pp. 32–38.) Description of a new design for interconnections of printed-circuit packages in the IBM 608 transistorized computer.

681.142 : 621.375.3 **3762**

Magnetic Computer has High Speed.—T. H. Bonn. (*Electronics*, 1st Aug. 1957, Vol. 30, No. 8, pp. 156–160.) Details are given of the magnetic-amplifier circuits and various types of core material.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.049.75 **3763**

Calculation of Stray Capacitances in Printed Circuit Assemblies of Radio Equipment.—L. M. Kononovich. (*Radiotekhnika, Moscow*, Aug. 1956, Vol. 11, No. 8, pp. 64–70.) The derivation of design formulae is based on a conformal transformation of printed conductors of various configurations into a coaxial long line.

621.316.82 : 621.314.63 **3764**

Some Characteristics of Metallic Varistors.—G. W. Holbrook & A. L. Dulmage. (*Electronic Engng*, Aug. 1957, Vol. 29, No. 354, pp. 386–392.) An attempt is make to provide an equivalent circuit which is applicable to all values of voltages within the rated limits, leading to an expression for describing the performance of the rectifier used as a variable resistor.

621.319.4 **3765**

A New Theorem in Electrostatics with Applications to Calculable Standards of Capacitance.—D. G. Lampard. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 271–280.)

621.372.412 **3766**

Standard Hyper-*Q* Quartz Crystal (100 kc/s GT-Cut).—Y. Hiruta. (*J. Radio Res. Labs, Japan*, April 1957, Vol. 4, No. 16, pp. 127–129.) A brief description with photographs and graphical data.

621.372.44 **3767**

Transient Response of Two-Terminal Networks.—O. P. D. Cutteridge. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 234–239.)

621.372.5 **3768**

Impedance Transformations by Extension of the Isometric Circle Method to the Three-Dimensional Hyperbolic Space.—E. F. Bolinder. (*J. Math. Phys.*, April 1957, Vol. 36, No. 1, pp. 49–61.) The analysis or synthesis of a lossy quadripole from three measurements and the cascading of lossy networks are considered.

621.372.5 : 621.372.8 : 621.318.134 **3769**

The Gyrator.—T. Roddam. (*Wireless World*, Sept. & Oct. 1957, Vol. 63, Nos. 9 & 10, pp. 423–426 & 497–500.) Non-reciprocity in certain electrical networks is discussed and compared with that in the mechanical gyroscope. A description is given of the classical physics background of the Faraday rotation in a nonreciprocal, microwave device, using a ferrite in an applied magnetic field.

621.372.5.029.6 **3770**

General Active, Passive and Non-reciprocal Quadripoles.—G. W. Epprecht. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st May 1957, Vol. 35, No. 5, pp. 169–193.) An introduction to quadripole theory with particular reference to microwave applications.

621.372.512 **3771**

An All-Pass Network.—W. P. Wilson. (*Electronic Radio Engr*, Oct. 1957, Vol. 34, No. 10, pp. 391–394.) A study of transient response in terms of a finite series of Laguerre functions.

621.372.512 **3772**

The Characteristics of All-Pass Sections.—W. Taeger. (*Frequenz*, May 1957, Vol. 11, No. 5, pp. 145–153.) Parallel-T and bridge networks with and without losses are discussed.

621.372.54 **3773**

Design Data for Symmetrical Darlington Filters.—J. K. Skwirzynski & J. Zdunek. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 366–380.) Practical design data are given in graphical form for symmetrical, equally terminated filters consisting of reactances only. Underlying theory is explained with practical hints for alignment of the network.

621.372.54 **3774**

Analysis and Synthesis of Transitional Butterworth-Thomson Filters and Band-Pass Amplifiers.—Y. Peless & T. Murakami. (*RCA Rev.*, March 1957, Vol. 18, No. 1, pp. 60–94.) A new class of filters, designated transitional Butterworth-Thomson (TBT), is described. These have more favourable transient characteristics than either the Butterworth- or Thomson-type filters.

621.372.54 : 519.241.1 **3775**

The Probability Distribution for the Filtered Output of a Multiplier whose Inputs are Correlated, Stationary, Gaussian Time Series.—D. G. Lampard. (*Trans. Inst. Radio Engrs*, March 1956, Vol. IT-2, No. 1, pp. 4–11. Abstract, *Proc. Inst. Radio Engrs*, July 1956, Vol. 44, No. 7, pp. 955–956.)

621.372.54.029.64 **3776**

An Improved Design Procedure for the Multisection Generalized Microwave Filter.—R. Levy. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 423–432.) An exact treatment of the *Q*-factor of a direct-coupled filter. Design formulae are given for the bandwidth, pass-band tolerance, and the attenuation in the rejection band for both quarter-wave-coupled and direct-coupled generalized filters.

621.372.54.029.64 : 621.372.8 **3777**

Microwave Filters utilizing the Cut-Off Effect.—P. A. Rizzi. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. MTT-4, No. 1, pp. 36–40. Abstract, *Proc. Inst. Radio Engrs*, April 1956, Vol. 44, No. 4, p. 581.)

621.373.076 **3778**

Posicast Control of Damped Oscillatory Systems.—O. J. M. Smith. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1249–1255.) A method of producing dead-beat response in a lightly damped oscillatory feedback system. It consists in exciting several transient oscillations with magnitudes and phases so adjusted that the resultant of the transient oscillation vectors is zero.

621.373.4 **3779**

External Influences on an Oscillator.—S. I. Evtyanov. (*Radiotekhnika, Moscow*, June 1956, Vol. 11, No. 6, pp. 3–12.) A mathematical analysis of the operation of an oscillator subjected to external influences. Both synchronous and asynchronous conditions of operation are considered.

621.373.4.029.63 **3780**

Energy Relations in an U.H.F. Valve Oscillator.—L. N. Kolesov. (*Radiotekhnika, Moscow*, June 1956, Vol. 11, No. 6, pp. 27–42.) The main energy relationships for an u.h.f. triode oscillator are derived; the effects of electron inertia and of the parameters of the oscillatory system are taken into account.

621.373.4.072.9 **3781**

Synchronization of Oscillators by Periodically Interrupted Waves.—D. W. Fraser. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1256–1268.) The principles, methods, circuit applications and the theoretical basis of synchronization are discussed. It is demonstrated theoretically and experimentally that the average frequency of the oscillator can be synchronized to the fundamental component or to any sideband of the interrupted signal.

621.373.42 **3782**

Uni-control Wide-Range Oscillator.—S. N. Das. (*Electronic Radio Engr*, Oct. 1957, Vol. 34, No. 10, pp. 365–368.) A single tank circuit between grid and anode of a triode uses a combination of a variable *LC* circuit and a variable short-circuited transmission line to give a frequency range of about 23 : 1 (e.g. 25–580 Mc/s). Transition from *LC* mode to transmission-line mode of operation is smooth.

621.373.42 **3783**

Synchronization of a Sinusoidal Valve Oscillator by a Subharmonic Signal.—T. A. Gaĭlit & I. I. Minakova. (*Radiotekhnika, Moscow*, July 1956, Vol. 11, No. 7, pp. 50–56.) Synchronization is considered for the case in which the frequency of the external signal is close to one of the subharmonics of the oscillator. Various operating conditions of the oscillator are investigated.

621.373.42 : 621.316.729 **3784**

Nonstationary Processes in Self-Oscillating Systems with Strong Excitation by Radio Pulses.—E. S. Voronin & I. I. Rogatnev. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 144–149.) The conditions for synchronization of a self-oscillating system are investigated.

621.373.421 **3785**

Synchronized Systems with Time Delay in the Loop.—Z. J. Jelonek & C. I. Cowan. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 388–397.) Filters in the feedback loop of synchronized oscillators can be represented under certain conditions by time delay networks. Stability and pulling effect are investigated.

621.373.421 : 621.376.32 **3786**

Further Studies on Asymmetrical Three-Phase Oscillator for Very Wide Frequency Deviation.—P. Kundu. (*Indian J. Phys.*, Feb. 1957, Vol. 31, No. 2, pp. 83–98.) The circuit described earlier (1650 of 1956) is modified so that the loop gain of the oscillator is less dependent on the frequency-selective elements. Performance is improved.

621.373.43+621.317.755 **3787**

High-Power Pulse Generators.—H. G. Bruijning. (*Tijdschr. ned. Radiogenoot.*, Jan. 1957, Vol. 22, No. 1, pp. 1–14. In English.) Description of (*a*) the development of a thyratron-controlled generator delivering 0·01-μs 200-kW pulses with repetition rate 2 000/sec for a short-pulse radar system; (*b*) a c.r.o. with a bandwidth of 400 Mc/s based on a design described by Janssen (1434 of 1951), but using a thyratron to generate the sampling pulse.

621.373.431.1 : 621.318.57 **3788**

Polyphase Multivibrator.—Ya E. Belen'ki & A. N. Svenson. (*Radiotekhnika, Moscow*, July 1956, Vol. 11, No. 7, pp. 39–45.) A circuit is described which requires half the number of valves and components of existing circuits.

621.373.44 **3789**

The Build-Up of Oscillations in an Oscillator Operating in the Decimetre Wavelength Range.—N. F. Alekseev. (*Radiotekhnika, Moscow*, Aug. 1956, Vol. 11, No. 8, pp. 52–63.) A method is described for decreasing the average delay of the leading edge of a pulse and for reducing the 'spread' of the delays. Experiments were carried out to determine the initial amplitudes of self-oscillation and free (damped) oscillation and also the pre-oscillatory noise. Pulses down to 0·1 μs can be generated even if an input pulse of moderate slope is used.

621.373.52 : 621.314.7 **3790**

Stable Transistor Oscillator.—E. Keonjian. (*Trans. Inst. Radio Engrs*, March 1956, Vol. CT-3, No. 1, pp. 38–44. Abstract, *Proc. Inst. Radio Engrs*, July 1956, Vol. 44, No. 7, p. 953.)

621.373.52 : 621.373.431.1 **3791**

Two-Terminal Analysis and Synthesis of Junction-Transistor Multivibrators.—J. J. Suran & F. A. Reibert. (*Trans. Inst. Radio Engrs*, March 1956, Vol. CT-3, No. 1, pp. 26–38. Abstract, *Proc. Inst. Radio Engrs.* July 1956, Vol. 44, No. 7, pp. 952–953.)

621.373.52 : 621.373.431.1 **3792**

The Astable Multivibrator using Junction Transistors.—V. Cimagalli. (*Alta Frequenza*, April/June 1957, Vol. 26, Nos. 2/3, pp. 159–184.) The behaviour of a transistor multivibrator is analysed on the basis of transistor theory by taking account of various transistor characteristics including the effect of minority-carrier storage, and close agreement with experimental results is found. A three-transistor square-wave generator is described, which produces a waveform of 1·35-V peak-to-peak amplitude and 0·13-μs rise time.

621.374.3 **3793**

Millimicrosecond Time-to-Pulse-Height Converter using an R.F. Vernier.—R. L. Chase & W. A. Higinbotham. (*Rev. sci. Instrum.*, June 1957, Vol. 28, No. 6, pp. 448–451.) Timing is accomplished by reference to the phase of a high-frequency (20-Mc/s) clock. This is indicated by the phase of a low-frequency (200-kc/s) beat note produced between the clock signal and one generated by the event to be timed.

621.374.3 **3794**

The Construction of a Device for Comparing Code Pulses, with Protection against False Operation, and an Investigation into the Operation of such a Device.—B. V. Rybakov. (*Radiotekhnika, Moscow*, July 1956, Vol. 11, No. 7, pp. 26–38.) A description is given of a device incorporating a new anti-coincidence circuit which prevents false operation caused by varying delays in the application and clearance of the pulses to be registered. The operation of the circuit is discussed in detail.

621.375 : 621.385.029.6 : 621.396.822 **3795**

The Minimum Noise Figure of Unmatched Amplifiers.—Pötzl. (See 4065.)

621.375.026+621.373.1] : 538.632 **3796**

The Hall Generator as Power Amplifier and Oscillator.—F. Kuhrt. (*Elektrotech. Z., Edn A*, 11th May 1957, Vol. 78, No. 10, pp. 342–344.) Brief description of the construction and operation of the Hall-effect 'multiplier' and its use as an oscillator. See also 3939 below.

621.375.123 **3797**

Degenerative *RC*-Coupled Amplifiers without Overshoot.—K. Fränz. (*Arch. elekt. Übertragung*, April 1957, Vol. 11, No. 4, pp. 159–162.) Conditions are derived for obtaining freedom from overshoot in multistage *RC*-coupled amplifiers with negative feedback.

621.375.13.029.4 **3798**

Positive Current Feedback in L.F. Amplifiers.—G. Ya. Gurovich. (*Radiotekhnika, Moscow*, June 1956, Vol. 11, No. 6, pp. 58–62.) Certain types of distortion can be compensated without lowering the amplification factor of the stage.

621.375.2.018.75 **3799**

A Linear-Logarithmic Amplifier for Ultra-Short Pulses.—H. Kihn & W. E. Barnette. (*RCA Rev.*, March 1957, Vol. 18, No. 1, pp. 95–135.) The development is described of a five-stage amplifier having an overall bandwidth of 180 Mc/s, centred on 180 Mc/s and a total dynamic range of 67 dB.

621.375.2.024 : 681.142 **3800**

Drift-Corrected D.C. Amplifier.—M. H. McFadden. (*Electronic Radio Engr*, Oct. 1957, Vol. 34, No. 10, pp. 358–364.) The need for drift correction is explained and a continuously drift-corrected amplifier, suitable for use in either a repetitive or real-time computer, is described.

621.375.2.029.4 **3801**

A Low-Frequency Amplifier with Fractional-Ohm Input Impedance.—K. Landecker. (*J. Electronics (Control*, Aug. 1957, Vol. 3, No. 2, pp. 218–224.) The low-impedance d.c. source is connected in series with a two-button carbon microphone, which is excited at 10 kc/s by a sound wave of constant amplitude. The interrupted ('chopped') current is fed via a 2 500/1 transformer into an amplifier tuned to 10 kc/s. Linear amplification is obtained from a fraction of a volt down to thermal noise voltages.

621.375.2.029.4 **3802**

The Consonant Amplifier-Limiter.—D. B. Daniel. (*Radio & Telev. News*, March 1957, Vol. 57, No. 3, pp. 49–51.) Circuit details and performance characteristics for an a.f. limiting device with fast response but without the distortion occurring in conventional 'clipper' circuits.

621.375.2.029.4 **3803**

A 3-Channel Amplifier.—K. W. Betsh. (*Radio & Telev. News*, March 1957, Vol. 57, No. 3, pp. 65–68.) This high-fidelity output amplifier incorporates variable electronic cross-overs and provision for e.s. loudspeakers.

621.375.2.133 **3804**

A 7- to 30-Mc/s Preselector.—E. L. Campbell. (*QST*, Feb. 1957, Vol. 41, No. 2, pp. 16–18.) The design of a regenerative pre-amplifier, which increases the overall gain and selectivity of existing equipment, is described.

621.375.232.3.029.3 **3805**

Triode Cathode-Followers: a Graphical Analysis for Audio Frequencies.—T. J. Schultz. (*Trans. Inst. Radio Engrs*, March/April 1956, Vol. AU-4, No. 2, pp. 42–45. Abstract, *Proc. Inst. Radio Engrs*, June 1956, Vol. 44, No. 6, Part 1, p. 830.)

621.375.3 : 621.3.042.001.4 **3806**

Core Tester Simplifies Ferro-amplifier Design.—R. W. Roberts & C. C. Horstman. (*Electronics*, 1st Aug. 1957, Vol. 30, No. 8, pp. 150–153.) A method of testing cores of magnetic material is described; the results are applied in normalized design equations for magnetic amplifiers.

621.375.4 : 621.3.087.6 : 616 **3807**

Transistor Amplifier for Medical Recording.—D. W. R. McKinley & R. S. Richards. (*Electronics*, 1st Aug. 1957, Vol. 30, No. 8, pp. 161–163.) "Pen-recorder amplifier provides transformerless system for recording 3-c/s heart signals. Modification of feedback circuit gives audio amplifier with up to 5-W output flat within 0·2 dB from 20 c/s to 20 kc/s."

621.375.4 : 621.314.7 **3808**

An *N*-Stage Series Transistor Circuit.—K. H. Beck. (*Trans. Inst. Radio Engrs*, March 1956, Vol. CT-3, No. 1, pp. 44–51. Abstract, *Proc. Inst. Radio Engrs*, July 1956, Vol. 44, No. 7, p. 953.)

621.375.4+621.314.7]. 012.8 **3809**

Electric-Network Representation of Transistors—a Survey.—Pritchard. (See 4047.)

621.375.4.024 **3810**

A Transistor D.C. Chopper Amplifier.—P. L. Burton. (*Electronic Engng*, Aug. 1957, Vol. 29, No. 354, pp. 393–397.) Junction transistors are used as a switch, linear a.c. amplifier and synchronous rectifier to raise a thermocouple output of 50 mV to about 3 V for telemetering purposes. Printed circuits are used, and the instrument is encapsulated to the size of a 2-in. cube.

621.375.4.029.45 **3811**

Distortion due to the Mismatch of Transistors in Push-Pull Audio-Frequency Amplifiers.—K. W. Gurnett & R. A. Hilbourne. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 411–422.) An analysis of the transistor parameter variations which give rise to even-harmonic distortion. To minimize the latter, some matching of transistor characteristics is necessary; simple matching techniques are described.

621.375.432.9 **3812**

The Emitter - Coupled Differential Amplifier.—D. W. Slaughter. (*Trans. Inst. Radio Engrs*, March 1956, Vol. CT-3, No. 1, pp. 51–53. Abstract, *Proc. Inst. Radio Engrs*, July 1957, Vol. 44, No. 7, p. 953.)

621.375.9.029.64 : 538.569.4 **3813**

Superregenerative Masers. — P. F. Chester & D. I. Bolef. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1287–1289.) The characteristics of a two-level maser amplifier operated both intermittently and superregeneratively are compared. The sensitivity of gain to changes in operating conditions is shown for the cases of continuous regeneration and superregeneration.

621.375.9.029.64 : 538.569.4 **3814**

Maximum Efficiency of the Solid-State Maser.—H. Heffner. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1289.) The efficiency of a three-state maser of the type proposed by Bloembergen (1062 of April) is estimated for operation at saturation.

621.376.223 **3815**

The Behaviour of Modulator Circuits with Complex and, in particular, Selective Terminations.—J. Gensel. (*Frequenz*, May & June 1957, Vol. 11, Nos. 5 & 6, pp. 153–159 & 175–185.) A quasilinear equivalent circuit is derived by means of which the linear and nonlinear distortion of modulators working into filters can be determined. The circuit parameters are tabulated for modulators of the ring, Cowan and series types. See also 2457 of 1955 (Tucker).

621.376.32 : 621.318.134 **3816**

Ferrites for F.M.—T. W. G. Calvert. (*Wireless World*, Oct. 1957, Vol. 63, No. 10, pp. 505–507.) Circuits utilizing the change in permeability of a ferrite under an applied magnetic field are described. Changes in inductance of about 1% are obtained from a control current passed through a winding on the core; a 50% change is possible with an external magnetic field. The upper limit in frequency is about 15 Mc/s.

621.396.822 **3817**

Experimental Investigations into the Law of the Peak Distribution of Fluctuations with respect to their Duration.—V. I. Tikhonov. (*Radiotekhnika, Moscow*, Aug. 1956, Vol. 11, No. 8, pp. 31–35.) Experimental methods are described for determining the density distribution of probability of electrical fluctuations at various levels. From the experimental results obtained a table is compiled which gives the total number of points recurring at a given level and in a given range, for various lengths of peaks and intervals in a noise waveform.

621.396.822 : 016 **3818**

A Bibliography on Noise.—P. L. Chessin. (*Trans. Inst. Radio Engrs*, Sept. 1955, Vol. IT-1, No. 2, pp. 15–31.) A comprehensive bibliography of material published up to 1954. An index of authors and a list of publishers is included. Entries are arranged under the following headings: (*a*) source works (text books); (*b*) internal noise sources; (*c*) external noise; (*d*) noise generation and measurements; (*e*) impulsive-type noise; (*f*) modulation and noise; (*g*) radar applications; (*h*) noise, communication and filtering; (*i*) statistical theory.

GENERAL PHYSICS

530.145.61 **3819**

Extension of WKB Equation.—C. E. Hecht & J. E. Mayer. (*Phys. Rev.*, 15th June 1957, Vol. 106, No. 6, pp. 1156–1160.) The WKB form for the classical region is used to obtain a simple form for the argument $z(x)$ which makes the solutions valid through the turning point and into the non-classical region.

535.13 **3820**

On a Class of Solutions of Maxwell's Electromagnetic Equations.—G. E. Hudson & D. H. Potts. (*Commun. pure appl. Math.*, Feb. 1956, Vol. 9, No. 1, pp. 33–43.)

536.2.01 : 621.3.09 **3821**

The Solution of a Thermal Conduction Problem by means of an Analogy.—H. Schlitt. (*Arch. Elektrotech.*, 12th Jan. 1957, Vol. 43, No. 1, pp. 51–58.) An exact solution of the problem is found by using a system of equations analogous to that of the quadripole equations for a finite homogeneous transmission line.

537.12 : 551.510.53 **3822**

Low-Energy Elastic Scattering of Electrons by Oxygen and Nitrogen.—P. Hammerling, W. W. Shine & B. Kivel. (*J. appl. Phys.*, July 1957, Vol. 28, No. 7, pp. 760–764.) The electron-atom interaction potential is formed from (*a*) the Hartree potential, (*b*) an exchange term, and (*c*) a polarization term. The calculated scattering cross-sections agree closely with experimental results.

537.222 : 621.385 **3823**

Electric Field of a Charged Spot Produced by an Electron Beam on the Surface of a Dielectric: Part 1.—V. Ya. Upatov. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 193–203.) The case of a uniformly charged spot, and that of a spot with Gaussian distribution of the surface charge are discussed.

537.226 **3824**

Theory of Dipole Orientation Process in the Dielectric based on the Concept of a Visco-elastic Model: Parts 1 & 2.—S. Sharan. (*J. Instn Telecommun. Engrs*, Dec. 1956 & March 1957, Vol. 3, Nos. 1 & 2, pp. 3–11 & 123–129.)

537.311.31 **3825**

Distribution Function for the Classic Electron Gas.—S. V. Tyablikov & V. V. Tolmachev. (*C. R. Acad. Sci. U.R.S.S.*, 21st June 1957, Vol. 114, No. 6, pp. 1210–1213. In Russian.) Brief mathematical analysis.

537.311.33 : 538.632 **3826**

Clarification of First-Order Semiconduction Effects through Use of Electrochemical Potentials.—J. A. Swanson. (*IBM J. Res. Developm.*, Jan. 1957, Vol. 1, No. 1, pp. 39–43.) The use of the electrochemical potentials simplifies the treatment of conduction effects when only small carrier concentration deviations are involved. Poisson's equation can be ignored in the first-order treatment of steady-state effects. Applications to Hall effect and probe potentials are considered.

537.311.62 **3827**

Skin Effect in Thin Films and Wires.—B. M. Bolotovski. (*Zh. eksp. teor. Fiz.*, March 1957, Vol. 32, No. 3, pp. 559–565.) Kinetic theory is used to derive skin-effect equations. An approximate method is given for obtaining the impedance of thin films or wires.

537.525.029.6 **3828**

Determination of the Coefficient of Diffusion and Frequency of Ionization in Microwave Discharges.—M. P. Madan, E. I. Gordon, S. J. Buchsbaum & S. C. Brown. (*Phys. Rev.*, 1st June 1957, Vol. 106, No. 5, pp. 839–843.) The parameters are derived from measurement of the rate of growth of the electron density in a microwave cavity, in which an electric field larger than that necessary for breakdown is applied.

537.533.7 : 538.561 **3829**

Radiation from a Point Charge Moving along the Boundary between Two Media.—V. E. Pafomov. (*Zh. eksp. teor. Fiz.*, March 1957, Vol. 32, No. 3, p. 610.) Expressions are derived for an electron moving along the boundary between two dielectrics.

537.56 **3830**

Statistical Mechanical Theory of Transport Phenomena in a Fully Ionized Gas.—W. E. Brittin. (*Phys. Rev.*, 1st June 1957, Vol. 106, No. 5, pp. 843–847.) Nonequilibrium statistical mechanics is applied to a system of charged particles interacting via the electromagnetic field. The particles and field are treated statistically both from the classical and quantum-statistical standpoints.

537.56 : 538.6 **3831**

Oscillations of a Cylindrical Plasma.—T. H. Stix. (*Phys. Rev.*, 15th June 1957, Vol. 106, No. 6, pp. 1146–1150.) A mathematical analysis, with physical interpretation, of natural modes of oscillation in a longitudinal magnetic field. Hydromagnetic waves and cyclotron-frequency resonance occur in two limiting cases.

538.3 **3832**

The Analogue of Kelvin's Theorem in Hydromagnetics.—J. De. (*Naturwissenschaften*, April 1957, Vol. 44, No. 8, p. 256. In English.)

538.566 : 535.31 **3833**

Reflection and Refraction of Electromagnetic Waves at Plane Interfaces.—W. E. Williams. (*J. Math. Phys.*, April 1957, Vol. 36, No. 1, pp. 26–35.) The general problem of an arbitrary e.m. wave incident on a dielectric slab between two different dielectrics is considered.

538.566 : 535.42 **3834**

The Diffraction of an Electromagnetic Wave by a Large Aperture.—R. F. Millar. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 240–250.) An approximate expression is obtained for the difference from unity of the transmission coefficient for plane waves at normal incidence of a large aperture of rather general form in a plane perfectly conducting screen. Details are given for an elliptical aperture. See also 2425 of August.

538.566 : 535.43] + 534.26 **3835**

High-Frequency Scattering of Electromagnetic Waves.—D. S. Jones. (*Proc. roy. Soc. A*, 21st May 1957, Vol. 240, No. 1221, pp. 206–213.) "The assumption that the illuminated region and the penumbra of a body scatter independently at high frequencies is used to obtain scattering coefficients for perfectly reflecting convex bodies in plane electromagnetic and sound waves. The formulae involve only the scattering coefficients of the circular cylinder and the geometry of the shadow boundary. One general result is that the electromagnetic scattering coefficient of a solid of revolution, when the direction of propagation of the incident wave is along the axis of revolution, is the average of the sound-hard and sound-soft scattering coefficients." See also 3010 of October.

538.566 : 537.56 **3836**

Growing Electromagnetic Waves.—V. A. Bailey. (*Phys. Rev.*, 15th June 1957, Vol. 106, No. 6, p. 1356.) A criticism of Piddington's paper (2030 of 1956), noting that his conclusions are based on a criterion contrary to Einstein's principle of special relativity (see e.g. 105 of 1952).

538.569.4 : 621.375.9.029.64 **3837**

Superregenerative Masers.—Chester & Bolef. (See 3813.)

538.569.4 : 621.375.9.029.64 **3838**

Maximum Efficiency of the Solid-State Maser.—Heffner. (See 3814.)

538.569.4.029.5 **3839**

Paramagnetic Resonance Detection along the Polarizing Field Direction.—G. Whitfield & A. G. Redfield. (*Phys. Rev.*, 1st June 1957, Vol. 106, No. 5, pp. 918–920.) Report of measurements on diphenyl picryl hydrazyl.

538.569.4.029.5 : 537.56 **3840**

Ion Cyclotron Resonance.—R. F. Saxe. (*Nature, Lond.*, 13th July 1957, Vol. 180, No. 4576, pp. 87–88.) Absorption detected in a low-pressure hydrogen discharge in radial electric and varying magnetic fields is thought to correspond to the cyclotron resonance of atomic ions.

538.569.4.029.6 **3841**

Microwave Absorption in Ethyl Chloride.—Krishnaji & G. P. Srivastava. (*Phys. Rev.*, 15th June 1957, Vol. 106, No. 6, pp. 1186–1190.) Variation with pressure is determined at 7 392 and 8 780 Mc/s, and the results are interpreted theoretically. The absorption is equivalent to a nonresonant Debye type, due to a zero-frequency (*Q*-branch) line.

538.569.4.029.6 **3842**

A Solid-State Paramagnetic-Resonance Spectrometer.—P. M. Llewellyn. (*J. sci. Instrum.*, June 1957, Vol. 34, No. 6, pp. 236–239.) A simple and sensitive instrument for use in the frequency range 9–10 kMc/s at temperatures down to 14°K.

538.569.4.029.6 : 535.343 **3843**

A 'Free Space' Absorption Cell for Microwave Spectroscopy.—C. C. Costain. (*Canad. J. Phys.*, March 1957, Vol. 35, No. 3, pp. 241–247.) "The absorption cell consists simply of a pyrex tube with a polystyrene lens and microwave horn at each end to couple to the standard microwave components. The lenses also serve as the vacuum windows. The attenuation at 8·5 mm wavelength is 3·4 dB for a 250 cm cell. Since there are no metal surfaces, this type of cell is very suitable for the investigation of reactive molecules."

538.63.001.57 **3844**

A Mechanical Model for Demonstrating Gyromagnetic Phenomena.—R. Pottel. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st May 1957, Vol. 35, No. 5, pp. 193–196.) The model described consists of an electrically driven gyroscope suitably suspended to simulate various magnetic effects.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.16 **3845**

German Radio Observatory Stockert.—T. Pederzani. (*Elect. Engng, N.Y.*, March 1957, Vol. 76, No. 3, pp. 196–200.) See also 1738 of June.

523.16 : 621.396.677.8 **3846**

New Radio Telescope.—(See 3749.)

523.16 : 621.396.677.833 **3847**

The Jodrell Bank Radio Telescope.—A. C. B. Lovell. (*Nature, Lond.*, 13th July 1957, Vol. 180, No. 4576, pp. 60–62.) The telescope is essentially a paraboloidal steel bowl 250 ft in diameter with the focus in the aperture plane built so that it can be directed towards any part of the sky. Details of the specification are given.

523.16 : 621.396.822 **3848**

Cosmic Radio-Noise Intensities below 10 Mc/s.—Correction to 3126 of October: for W/cm², please read W/m².

523.16 : 621.396.822 **3849**

Some Interesting Variations of Background Noise Observed at a Frequency of 17·6 Mc/s.—W. N. Abbott. (*J. atmos. terr. Phys.*, 1957, Vol. 11, No. 1, pp. 72–74. In French.) Cosmic noise signals at 17·6 Mc/s are found to be weaker 1–3 h after sunset than 1 h before sunset with a reversal of the effect nearer the critical frequency. The effect may be due to the ionosphere.

523.5 : 621.396.96 **3850**

Radar Echoes from Overdense Meteor Trails under Conditions of Severe Diffusion.—G. S. Hawkins. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1290–1291.) Formulae for the echo power and scattering cross-section are developed. A nomogram is given for computing the radar cross-section of diffuse trails. See also 3717 of 1956.

523.53 **3851**

The Time Distribution of Meteors.—K. R. R. Bowden & J. G. Davies. (*J. atmos. terr. Phys.*, 1957, Vol. 11, No. 1, pp. 62–66.) Analysis of records of transient echoes at 36 Mc/s and 72 Mc/s shows no evidence to support previous suggestions that the meteors producing the echoes enter the atmosphere in groups or that many of the echoes are in fact due to cloud discharges.

523.75 : 621.396.11 **3852**

On the Disturbances of Radio Propagation along the North Polar Route.—Hakura. (See 3986.)

550.385 : 523.75 **3853**

Magnetic Activity following a Solar Flare.—R. A. Watson. (*J. atmos. terr. Phys.*, 1957, Vol. 11, No. 1, pp. 59–61.) "Evidence is examined which suggests that either there is no increase of magnetic activity due to a solar flare or that the increase is a very rare event".

550.385 : 523.78 **3854**

The Fine Structure of the Geomagnetic Solar Eclipse Effect.—H. Volland. (*J. atmos. terr. Phys.*, 1957, Vol. 11, No. 1, pp. 1–13. In German.) The extension of the theory of the solar eclipse effect in the geomagnetic field by the introduction of empirical functions, and a detailed discussion of the induction in the earth's interior and other influences, makes possible a quantitative interpretation of the effect. As a result of the height dependence of the location of the shadow centre, the height for the effective centre of the current-carrying layer can be decided. A method of determining the direction of the S_q current during an eclipse is mentioned.

550.389.2 **3855**

The International Geophysical Year.—(*Radio, Moscow*, May 1957, No. 5, pp. 20–21.) Outline of the world-wide program involving 5 000 scientists. Some special equipment to be used by the U.S.S.R. is mentioned, such as panoramic ionospheric recording equipment and a statistical analyser for noise and interference. The earth satellite is also discussed.

550.389.2 **3856**

The International Geophysical Year.—M. Nicolet. (*Nature, Lond.*, 6th July 1957, Vol. 180, No. 4575, pp. 7–10.) Outline of activities of the stations participating in the I.G.Y. program. Tables give the number of stations, their location and their function.

550.389.2 **3857**

Amateur Radio and the I.G.Y.—R. L. Smith-Rose. (*R.S.G.B. Bull.*, March 1957, Vol. 32, No. 9, pp. 396–397.) Suitable projects for radio amateurs in different countries are suggested and the procedure for participation is outlined.

550.389.2 **3858**

N.B.S. Participation in the International Geophysical Year.—(*Tech. News Bull. nat. Bur. Stand.*, Sept. 1957, Vol. 41, No. 9, pp. 136–140.) The greatest part of the Bureau's efforts will be concerned with the ionosphere, including the phenomena of sporadic *E* and of forward scatter. In addition there are programs of work on radio noise, whistlers, the 'dawn chorus' and airglow. The Bureau is responsible for for the World Warning Agency (3128 of October). During the I.G.Y. 12 stations will be directly operated by the Bureau and 25 operated in close association with it.

550.389.2 **3859**

In the Arctic and Antarctic.—(*Radio, Moscow*, May 1957, No. 5, pp. 12–13.) Five short notes on Russian observation posts including the Antarctic base of Mirnyĭ, where solar radiation, and ionospheric and atmospheric disturbances will be investigated during the I.G.Y. Radio wave propagation and the aurora will also be studied.

550.389.2 : 629.19 **3860**

Artificial Earth Satellites.—V. Vakhnin. (*Radio, Moscow*, June 1957, No. 6, pp. 14–17.) Information for radio amateurs taking part in the I.G.Y. program. General data regarding the orbit of the U.S.S.R. satellite are given, its functions are outlined and the problem of signal reception from it is discussed.

550.389.2 : 629.19 **3861**

Observations of Radio Signals from an Artificial Earth Satellite and their Scientific Significance.—A. Kazantsev. (*Radio, Moscow*, June 1957, No. 6, pp. 17–19.) A U.S.S.R. satellite launched during the I.G.Y. will be equipped with two 1-W transmitters operating at 20 and 40 Mc/s respectively, alternately transmitting pulse signals of 0·05–0·7 sec duration from above the F layer.

550.389.2 : 629.19 **3862**

The Observation of Signals from Artificial Earth Satellites.—(*Radio, Moscow*, July 1957, No. 7, pp. 17–25.) Basic transmitter data of the U.S.A. and U.S.S.R. satellites (see also 3861 above) are summarized. The following two papers outline methods and describe equipment for use by amateurs in locating the satellites, and a further paper deals with the proposed U.S.A. satellite.

U.S.W. Receiver.—O. Rzhiga & A. Shakhovskoĭ (pp. 17–20).

Radiolocation Unit.—V. Dubrovin (pp. 21–23).

550.389.2 : 629.19 **3863**

The Observation of Signals from Artificial Earth Satellites.—(*Radio, Moscow*, Aug. 1957, No. 8, pp. 17–20.)

Method of Observation.—O. Rzhiga & A. Shakhovskoĭ (pp. 17–19).

Work done with the Direction-Finding Equipment.—V. Dubrovin (pp. 19–20).

Methods are outlined for the observation and recording of signals from a satellite and for determining the instant of its passage overhead. A brief description is given of receiving equipment, and reference is made to its experimental use with an airborne transmitter, illustrating the change in the received signal when the aircraft passes overhead. See also 3862 above.

551.510.535 **3864**

Tabulation of the Vertical Group Velocities of Ordinary Ionospheric Echoes.—W. Becker. (*Arch. elekt. Übertragung*, April 1957, Vol. 11, No. 4, pp. 166–172.) Expanded tables of group refractive index for the ordinary ray including values to 4 decimal places given by Shinn (*The Physics of the Ionosphere*, 1955, pp. 402–406) and 6-figure values calculated by the author covering an extended range of gyromagnetic frequencies.

551.510.535 **3865**

Measurement of the Gyro Frequency in the F Region.—G. R. Ellis. (*J. atmos. terr. Phys.*, 1957, Vol. 11, No. 1, pp. 54–58.) The gyro frequency at 378 km is calculated using triple splitting of f_0F_2. The results are 10% higher than would be expected using an extrapolated ground-level value.

551.510.535 : 523.75 **3866**

The Influence of Solar Flares on the Ionospheric E Layer.—J. Taubenheim. (*J. atmos. terr. Phys.*, 1957, Vol. 11, No. 1, pp. 14–22. In German.) Solar-flare effects in the E layer are examined quantitatively for selected days. It is concluded that the observed variation in electron density is controlled by the slow decrease of excess radiation rather than by recombination.

551.510.535 : 523.78 **3867**

Investigation of Discrete Sources of Radiation from Solar Eclipse Observations.—N. Mitra. (*Indian J. Phys.*, Feb. 1957, Vol. 31, No. 2, pp. 69–82.) Ionospheric observations during the partial solar eclipse (89·5%) of 20th July 1944 have been critically examined in order to determine whether the reduction of ion density of the E layer with the progress of the eclipse follows Chapman's theory of layer formation based on a homogeneous distribution of radiation across the solar disk.

551.510.535 : 621.396.11 **3868**

Oblique Ray Paths in the Ionosphere.—Haselgrove. (See 3990.)

551.510.535 : 621.396.11 **3869**

Application of the Generalized Magneto-Ionic Theory to the Propagation of Radio Waves at the Magnetic-Dip Poles of the Earth.—Bai. (See 3989.)

551.510.535 : 621.396.812.3 **3870**

An Experimental Verification of Diffraction Microscopy, using Radio Waves.—G. L. Rogers. (*J. atmos. terr. Phys.*, 1957, Vol. 11, No. 1, pp. 51–53.) An aircraft was flown over a Mitra spaced aerial system and the fading pattern analysed. See also 2749 of September.

551.594.5 **3871**

H_α Emissions during Aurorae over West-Central Canada.—R. Montalbetti & A. V. Jones. (*J. atmos. terr. Phys.*, 1957, Vol. 11, No. 1, pp. 43–50.) H_α emission in aurorae does not support Martyn's theory of a diurnal variation of the sign of auroral particles. It does show that with increasing magnetic disturbance, the southern fringe of strong emission moves southward. H_α emission, unlike some nitrogen bands, can be completely missing from strong aurorae.

551.594.6 : 621.396.11 **3872**

Heavy-Ion Effects in Audio-Frequency Radio Propagation.—Hines. (See 3991.)

LOCATION AND AIDS TO NAVIGATION

621.396.96 : 621.395.625.3 **3873**

The Fundamentals of the Storing of Radar Displays on Magnetic Tape.—W. H. Schönfeld & H. Gillmann. (*Elektronische Rundschau*, June 1957, Vol. 11, No. 6, pp. 165–167.) Outline of experimental recording system for use with bandwidth compression equipment such as described by Groll et al. (3874 below).

621.396.96 : 621.395.625.3 : 621.397.2 **3874**

Frequency Compression Equipment for Long-Distance Transmission and Magnetic Tape Recording of Radar Displays.—H. Groll, K. Dinter & K. Lange. (*Elektronische Rundschau*, May 1957, Vol. 11, No. 5, pp. 155–157.) Brief description of equipment for bandwidth compression using methods discussed in 3744 of 1956 (Meinke & Groll).

621.396.96 : 681.14 **3875**

'Nearest Approach' Calculator.—A. L. P. Milwright. (*Wireless World*, Oct. 1957, Vol. 63, No. 10, pp. 475–476.) A simple device for obtaining directly, from observations on a true-motion marine radar, the closest approach between two ships which continue on their observed courses.

621.396.96.029.64 **3876**

The Calculation of the Effective Reflection Area of a Surface Target in the Centimetre Wavelength Range.—G. I. Perov. (*Radiotekhnika, Moscow*, July 1956, Vol. 11, No. 7, pp. 57–59.) Errors are discussed which arise in the derivation of formulae for the effective reflection area when the earth's surface is irradiated by pulses, and for the directivity factor of an aircraft aerial.

621.396.967 : 621.317.3 **3877**

Test Set for 3-cm Radar Equipment.—J. Verstraten. (*Philips Telecommun. Rev.*, April 1957, Vol. 17, No. 4, pp. 123–130.) Measurements can be made of transmitter frequency and pulse length, forward and reflected aerial power, receiver noise figure and other equipment parameters for all frequencies from 8·5 to 9·6 kMc/s.

621.396.968 : 621.376.239 : 621.396.822 **3878**

An Analysis of Signal Detection and Location by Digital Methods.—G. P. Dinneen & I. S. Reed. (*Trans. Inst. Radio Engrs*, March 1956, Vol. IT-2, No. 1, pp. 29–38. Abstract, *Proc. Inst. Radio Engrs*, July 1956, Vol. 44, No. 7, p. 956.)

MATERIALS AND SUBSIDIARY TECHNIQUES

535.215 : 537.311.33 **3879**

Influence of the External Potential and Other Factors on the Capacitor Photo-Response of Semiconductors.—V. E. Kozhevin & V. E. Lashkarev. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 260–268.) Several semiconductors including MgI_2, PbI_2, CdS, with dielectric layers of mica, cellophane-mica or cellophane were investigated by means of the capacitor method. The polarity of photocurrent carriers and the spectral distribution of photosensitivity were recorded.

535.215 : 537.311.33 **3880**

The Influence of Molecular Adsorption and the External Electrical Field on the Photoconductivity of Semiconductors.—V. I. Lyashenko & O. V. Snitko. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 269–277.) The method and results of an experimental investigation of the photoconductivity of Cu_2O and molybdenum sulphide are discussed.

535.215 : 546.23 : 539.23 **3881**

Transit-Time Measurements of Charge Carriers in Amorphous Selenium Films.—W. E. Spear. (*Proc. phys. Soc.*, 1st July 1957, Vol. 70, No. 451B, pp. 669–675.) Measured effective carrier mobilities at room temperature are between $4{\cdot}7$ and $5{\cdot}5 \times 10^{-3}$ cm^2/V. sec for electrons and about $0{\cdot}15$ cm^2/V. sec for holes. The temperature dependence of the mobilities indicates trapping levels which for electrons are 0·25 eV and for holes are 0·16 eV below the conduction band.

535.215 : 546.482.21 **3882**

Thermal and Electrolytic Activation of Photoconductivity in CdS Crystals.—J. Woods. (*J. Electronics Control*, Aug. 1957, Vol. 3, No. 2, pp. 225–235.) Two processes whereby the photoconductivity of CdS crystals increases on heating are described. The previously reported activation of CdS by dielectric breakdown (1114 of April) is explained in terms of these thermal effects.

535.215 : 546.482.21 **3883**

The Form of Spectral Distribution of Photoconductivity in Single Crystals of CdS.—V. E. Lashkarev, E. A. Sal'kov, G. A. Fedorus & M. K. Sheĭnkman. (*C. R. Acad. Sci. U.R.S.S.*, 21st June 1957, Vol. 114, No. 6, pp. 1203–1205. In Russian.) Carrier mobility was found to be independent of λ in the experimental range 4 500–5 500 Å. The causes of the drop in photocurrent were investigated. Results are shown in graphical form.

535.215 : 546.492.151 **3884**

Photoelectric and Optical Properties of HgI_2.—D. V. Chepur. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 278–286.) The lifetime of photocurrent carriers for specimens illuminated by light of differing wavelengths, their quantum efficiency as dependent on temperature, and the optical properties of HgI_2 are discussed.

535.215 : 546.57.131 **3885**

Inertia of the Internal Photo-effect in Silver Chloride.—K. K. Demidov. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 350–351.) The carrier lifetime in specimens of AgCl under monochromatic light of $\lambda = 400$ to 500 mμ is decreased by additional illumination at $\lambda = 600$ to 900 mμ.

535.215 : 546.817.221 **3886**

Onset of Photo-e.m.f. in Layers of Lead Sulphide.—R. Ya. Berlaga, M. A. Rumsh & L. P. Strakhov. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 287–290.) Electron diffraction patterns and the microscopic examination of vapour-deposited layers of PbS show the existence of needle-shaped protuberances. The relation of needle orientation to photoelectric characteristics is examined.

535.215 : 546.817.231 **3887**

The Effect of Oxygen on an Evaporated PbSe Layer.—R. H. Jones. (*Proc. phys. Soc.*, 1st July 1957, Vol. 70, No. 451B, pp. 704–708.) An investigation of the mechanism by which oxygen produces photoconductive sensitivity.

535.37 **3888**

Luminescence of Silver Bromoiodide Crystals.—F. Moser & F. Urbach. (*Phys. Rev.*, 1st June 1957, Vol. 106, No. 5, pp. 852–858.) Low-temperature measurements are reported. Trapping has been investigated by a study of the slow build-up of fluorescence under weak excitation.

535.371 : 546.321.31 **3889**

Colour Centres in Crystals of KCl, and KCl with Ag Added.—N. G. Politov. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 291–295.) The absorption spectrum of single crystals is examined. The spectrum changes after irradation with ultraviolet and X rays are also considered.

535.376 : 546.281.26 **3890**

Structure and Characteristics of Silicon Carbide Light-Emitting Junctions.—L. Patrick. (*J. appl. Phys.*, July 1957, Vol. 28, No. 7, pp. 765–776.) Junctions, where the leakage at the periphery and through 'blue spots' has been reduced to a minimum, are found to have a p-n^*-n structure. A theory of the forward characteristic of the p-n^*-n junction is given which explains the characteristics observed and their dependence upon temperature. The results of experiments on crystal growing, and an explanation of the growth of light-emitting junctions are given.

535.376 : 546.472.21 **3891**

Temperature Dependence of Electroluminescence.—C. H. Haake. (*J. electrochem. Soc.*, May 1957, Vol. 104, No. 5, pp. 291–298.) Measurements were made over wide ranges of temperature and frequency on a number of powdered single-band ZnS phosphors containing Cu, Cu-Pb, O_2 and Cl impurities. From the temperature dependence of photoluminescence a thermal extinction factor was derived, which when introduced in the electroluminescence brightness values led to an ideal electroluminescence brightness unaffected by thermal quenching. In general this ideal brightness was found to increase or tend to saturation with increasing temperature, but did not decrease.

537.226/.227 : 546.431.824-31 **3892**

Microstructure of Barium Titanate Ceramics.—R. C. DeVries & J. E. Burke. (*J. Amer. ceram. Soc.*, 1st June 1957, Vol. 40, No. 6, pp. 200–206.) Using polishing and etching techniques, structural changes due to the application of a d.c. field can be seen.

537.226/.227 : 546.431.824-31 **3893**

Domain Orientation in Barium Titanate Single Crystals.—D. P. Cameron. (*IBM J. Res. Developm.*, Jan. 1957, Vol. 1, No. 1, pp. 2–7.)

537.226/.227 : 546.431.824-31 **3894**
: 537.311.33

Electrical Properties of $BaTiO_3$ containing Samarium.—G. G. Harman. (*Phys. Rev.*, 15th June 1957, Vol. 106, No. 6, pp. 1358–1359.) Unusual resistivity variations were associated with crystallographic transitions. From 0 to 120°C, the resistivity was independent of temperature; from 120 to 250°C, it rose rapidly. Below 0°C, semiconducting properties were found.

537.227 **3895**

Dielectric Constant and Conductivity of Guanidine Aluminium Sulphate during Switching.—M. Prutton. (*Proc. phys. Soc.*, 1st July 1957, Vol. 70, No. 451B, pp. 702–703.)

537.228.1 **3896**

Anisotropy in Polarized Barium Titanate Ceramics.—M. Marutake & T. Ikeda. (*J. phys. Soc. Japan*, March 1957, Vol. 12, No. 3, pp. 233–240.)

537.311.32 : 546.212-16 **3897**

The Electrical Conductivity of Ice.—R. S. Bradley. (*Trans. Faraday Soc.*, May 1957, Vol. 53, Part 5, pp. 687–691.) "The d.c. electrical conductivity κ of ice has been determined at 0 to −25°C, and is given by $\kappa = 23{\cdot}4 \exp(-12\,300/RT)$ ohm^{-1}. cm^{-1}. The results are discussed in terms of proton migration and semiconductor theory."

537.311.33 **3898**

An Analysis of Diffusion in Semiconductors.—S. Zaromb. (*IBM J. Res. Developm.*, Jan. 1957, Vol. 1, No. 1, pp. 57–61.) It is shown that the usual Fick's laws may not apply to the diffusion of impurities in semiconductors. Appreciable covalent compound formation is likely to occur between some substitutional donors and acceptors, leading to a marked dependence of diffusion coefficients on concentration, and to interaction between donor and acceptor diffusion effects.

537.311.33 **3899**

Carrier Generation and Recombination in *P-N* Junctions and *P-N* Junction Characteristics.—C. T. Sah, R. N. Noyce & W. Shockley. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1228–1243.) For certain p-n junctions the measured current/voltage characteristics deviate from the ideal case of the diffusion model. It is shown that the current due to generation and recombination of carriers from generation-recombination centres in the space-charge region of a p-n junction accounts for the observed characteristics. The relative importance of the diffusion current outside the space-charge layer and the recombination current inside the space-charge layer also explains the increase of the emitter efficiency of Si transistors with emitter current.

537.311.33 **3900**

Determination of Optical Constants and Carrier Effective Mass of Semiconductors.—W. G. Spitzer & H. Y. Fan. (*Phys. Rev.*, 1st June 1957, Vol. 106, No. 5, pp. 882–890.) By means of reflectivity and absorption measurements in the region 5–35 μ, the effect of free carriers on the optical constants has been determined for n- and p-type Ge, Si and InSb, and for n-type InAs.

537.311.33 **3901**

Experimental Determination of Injected Carrier Recombination Rates at Dislocations in Semiconductors.—J. P. McKelvey. (*Phys. Rev.*, 1st June 1957, Vol. 106, No. 5, pp. 910–917.) The recombination probabilities associated with lineage boundaries in Ge have been determined by measuring the ratio of injected-carrier concentration on either side of such a boundary. The capture cross-sections for a single dislocation correspond to circular recombination areas of diameter 1·15Å for holes in n-type Ge and 2·8Å for electrons in p-type Ge.

537.311.33 **3902**

An Empirical Regularity of Energy Gap in Semiconductors.—T. Miyauchi. (*J. phys. Soc. Japan*, March 1957, Vol. 12, No. 3, p. 308.) An empirical linear relation exists for several groups of compounds between the energy gap and r_1/r_2 where r_1 is half the nearest neighbour distance and r_2 is an average of the positive ionic radius.

537.311.33 **3903**

Prediction of Semiconductor Surface Response to Ambients by Use of Lewis Acid-Base Theory.—C. G. Peattie & J. R. Macdonald. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, p. 1292.) In this treatment a p-type surface is considered a Lewis acid (electron-pair acceptor) and an n-type surface a Lewis base (electron-pair donor).

537.311.33 : 546.28 **3904**

Growth of Silicon Crystals by a Vapour-Phase Pyrolytic Deposition Method.—R. C. Sangster, E. F. Maverick & M. L. Croutch. (*J. electrochem. Soc.*, May 1957, Vol. 104, No. 5, pp. 317–319.) Si crystals are grown by the reaction of gaseous $SiBr_4$ with H_2 at the surfaces of hot Si seed filaments.

537.311.33 : 546.28 **3905**

Some Observations of the Effects of Oxygen on the Minority-Carrier Lifetime and Optical Absorption of Silicon Crystals Pulled in Vacuo.—G. W. Freen, C. A. Hogarth & F. A. Johnson. (*J. Electronics Control*, Aug. 1957, Vol. 3, No. 2, pp. 171–182.) Discusses the technique of growing single crystals by pulling from a melt in vacuo. For such crystals the carrier lifetime decreases radially from the centre. This decrease is attributed to the smaller amount of oxygen impurity near the surface, as shown by optical absorption measurements. In a vacuum oxygen is evaporated from the surface and removed by pumping.

537.311.33 : 546.28 **3906**

Diffusion of Oxygen in Silicon.—R. A. Logan & A. J. Peters. (*J. appl. Phys.*, July 1957, Vol. 28, No. 7, pp. 819–820.) The diffused layer is revealed by etching, or by heating at 450°C the resultant n layer being demarcated by staining in HF, by the thermal probe technique, or by gold displacement plating.

537.311.33 : 546.28 **3907**

Retrograde Solubility of Aluminium in Silicon.—D. Navon & V. Chernyshov. (*J. appl. Phys.*, July 1957, Vol. 28, No. 7, pp. 823–824.) The solubility near the eutectic temperature, and the diffusion constants as measured by Al diffusion from an Al-Si are examined.

537.311.33 : 546.28 : 535.215 **3908**

Analysis of the Photoconductance in Silicon.—L. J. van der Pauw. (*Philips Res. Rep.*, Aug. 1957, Vol. 12, No. 4, pp. 364–376.) A general expression is derived in terms of bulk and surface properties for the change in the voltage drop across a semiconductor sample due to illumination. The experimental determination of these properties from the low-frequency phase shift between the voltage change and a sinusoidally modulated light signal is illustrated, and results of measurements on n- and p-type Si at room temperature are discussed.

537.311.33 : 546.28 : 539.164.9 **3909**

A Transformation of *p*-Si into *n*-Si by X Rays.—F. Trey & F. Oberhauser. (*Naturwissenschaften*, April 1957, Vol. 44, No. 8, pp. 256–257.) Brief report of experimental results obtained with a single-crystal specimen.

537.311.33 : 546.28 : 669.046.54/.55 **3910**

Contribution to the Floating-Zone Refining of Silicon.—E. Buchler. (*Rev. sci. Instrum.*, June 1957, Vol. 28, No. 6, pp. 453–460.)

537.311.33 : 546.289 **3911**

Thermoelectric Power and Resistivity of Solid and Liquid Germanium in the Vicinity of its Melting Point.—C. A. Domenicali. (*J. appl. Phys.*, July 1957, Vol. 28, No. 7, pp. 749–753.) The absolute thermoelectric power Q of high-purity Ge is approximately linear in $1/T$ for 400°C$<T<$937°C. For liquid Ge Q is nearly zero and independent of temperature. The thermoelectric power of liquid relative to solid Ge is $+70\,\mu$V/°C.

537.311.33 : 546.289 **3912**

The $L_{\beta 3}$ and $L_{\beta 4}$ Lines in the Spectrum of Germanium.—G. P. Borovikova & M. I. Korsunski. (*C. R. Acad. Sci. U.R.S.S.*, 21st June 1957, Vol. 114, No. 6, pp. 1192–1194. In Russian.) Report of investigations on single-crystal high-purity Ge.

537.311.33 :546.289 **3913**

Depth of Surface Damage due to Abrasion on Germanium.—B. A. Irving: T. M. Buck & F. S. McKim. (*J. electrochem. Soc.*, June 1957, Vol. 104, No. 6, pp. 396–397.) Comment on 2186 of July and authors' reply.

537.311.33 : 546.289 : 535.215 : 538.63 **3914**

Experiments on the Photomagnetoelectric Effect in Germanium.—T. M. Buck & F. S. McKim. (*Phys. Rev.*, 1st June 1957, Vol. 106, No. 5, pp. 904–909.) Measurements of the PME short-circuit current and relative increase in conductance have been made over a wide range of light intensity. Results are in accord with the theory of van Roosbroeck (2780 of 1956).

537.311.33 : 546.682.86 **3915**
: 669.046.54/.55

The Role of Evaporation in Zone Refining Indium Antimonide.—K. F. Hulme & J. B. Mullin. (*J. Electronics Control*, Aug. 1957, Vol. 3, No. 2, pp. 160–170.) "Experiments on the refining of InSb are described; they include work with material heavily doped with Zn, Cd, Te, and As. Several lines of evidence show that the important acceptor impurities Zn and Cd are volatile from molten InSb. The removal of acceptors by volatilization under appropriate experimental conditions, followed by zone refining, can yield material with less than 10^{14} excess donors per cm^3."

537.311.33 : 546.817.221 **3916**

Interstitial Diffusion of Copper in PbS Single Crystals.—J. Bloem & F. A. Kröger. (*Philips Res. Rep.*, Aug. 1957, Vol. 12, No. 4, pp. 281–302.) Report and discussion of results of an experimental investigation showing that at temperatures between 100° and 500°C Cu can diffuse rapidly into PbS via interstitial sites, causing n-type conductivity.

537.311.33 : 546.817.221 **3917**

Interstitial Diffusion of Nickel in PbS Single Crystals.—J. Bloem & F. A. Kröger. (*Philips Res. Rep.*, Aug. 1957, Vol. 12, No. 4, pp. 303–308.) "Under reducing conditions, nickel may penetrate into PbS crystals at temperatures $T<500$°C at which the self-diffusion in PbS is negligible; it diminishes p-type conductivity and may cause n-type conductivity with donors of a depth $E \approx 0\cdot03$ eV. The diffusion probably takes places via the interlattice with a diffusion constant $D_{Ni} = 17\cdot8 \exp(-22\,000/RT)$ cm^2 sec^{-1}. Under sulphurizing conditions (H_2S) the nickel can be drawn out of the crystal again and the original conductivity restored."

537.311.33 : 546.817.241 **3918**

On Electrical Resistivity and Hall Coefficient of PbTe Crystals. — K. Shogenji & S. Uchiyama. (*J. phys. Soc. Japan*, March 1957, Vol. 12, No. 3, pp. 252–258.) Results of measurements on PbTe crystals give the intrinsic energy gap as 0·3 eV, and electron/hole mobility ratio as 2·5 with a $T^{-5/2}$ law for hole mobility.

537.311.33 : 621.3.082.52 **3919**

Pulsed Light tests Minority-Carrier Life.—H. L. Armstrong. (*Electronics*, 1st Aug. 1957, Vol. 30, No. 8, p. 145.) "Xenon discharge tube is rapidly pulsed to illuminate semiconductor material creating hole-electron pairs. Voltage drop across material is observed on oscilloscope to determine minority-carrier lifetime."

537.311.33 : 621.314.63 **3920**

Experimental Investigation of the Transient Behaviour of Gold-Germanium Surface Barriers.—O. Curtis, Jr, & B. R. Gossick. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. ED-3, No. 4, pp. 163–167. Abstract, *Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, p. 254.)

537.311.33 : 621.314.632 : 621.357.6 **3921**

A Quantitative Theory of the Electroformation of Metal/Germanium Point Contacts.—A. C. Sim. (*J. Electronics Control*, Aug. 1957, Vol. 3, No. 2, pp. 139–159.) The characteristics of Ge point contacts are improved by electroforming, in which local heating and melting are induced by a current pulse. A quantitative calculation supports the empirical findings that a high-impedance source for the current pulse is desirable, and that the pulse length should be greater than 20 ms for reproducible results. The improvement obtained with initial microsecond pulses of up to 20 A is discussed and studied theoretically.

537.311.4 : 621.3.066.6 **3922**

A Survey of Contact Resistance Theory for Nominally Clean Surfaces.—W. B. Ittner, III, & P. J. Magill. (*IBM J. Res. Develop.*, Jan. 1957, Vol. 1, No. 1, pp. 44–48.)

537.533 : 546.482.21 **3923**

Investigations of Cold Electron Emission from Cadmium Sulphide Single Crystals.—R. Rompe. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 219–221.) Experiments carried out at 10^{-5} mm Hg pressure showed that electron emission from CdS crystals for 7 kV between anode and cathode produced a current of 10^{-7}A, and for 12·5 kV this increased to 10^{-3}A.

538.22 : 546.3-1-711-47-26 **3924**

New Type of Magnetic Transition in Mn_3ZnC.—B. N. Brockhouse & H. P. Myers. (*Canad. J. Phys.*, March 1957, Vol. 35, No. 3, pp. 313–323.) "X-ray and neutron diffraction measurements are reported which demonstrate that at 231°K there is a second order transition below which ordering of the manganese ions occurs, resulting in a tetragonal distortion of the normally cubic lattice and a complex magnetic structure. One possible magnetic structure is discussed. Above the transition the alloy is apparently a normal ferromagnetic substance."

538.221 : 538.569.4 : 539.23 **3925**

Stress in Evaporated Ferromagnetic Films.—J. R. MacDonald. (*Phys. Rev.*, 1st June 1957, Vol. 106, No. 5, pp. 890–892.) Ferromagnetic resonance and oscillation-magnetometer measurements on a thin evaporated nickel film annealed in a magnetic field are described. The magnetic annealing produced a preferred magnetic axis in the plane of the film.

538.221 : 538.632 : 539.23 **3926**

Hall Effect and Ferromagnetism of Very Thin Nickel Films.—R. Coren & H. J. Juretschke. (*J. appl. Phys.*, July 1957, Vol. 28, No. 7, pp. 806–809.) The extraordinary Hall constant for films less than 100 Å thick, at room temperatures, is much greater than for bulk nickel.

538.221 : 621.318.122 **3927**

Supermendur, a New Rectangular-Loop Magnetic Material.—H. L. B. Gould & D. H. Wenny. (*Elect. Engng, N.Y.*, March 1957, Vol. 76, No. 3, pp. 208–211.) Characteristics are given of a Va-Fe-Co alloy which should be particularly useful for power applications. See also 2835 of September.

538.221 : [621.318.124+621.318.134 **3928**

Certain Properties of Ferrites.—J. K. Galt. (*Bell Lab. Rec.*, April 1957, Vol. 35, No. 4, pp. 126–130.) Basic description of the chemical structure and magnetic behaviour of ferrites. The loss mechanisms acting in ferromagnetic materials are outlined.

538.221 : 621.318.124 **3929**

Temperature Dependence of Spontaneous Magnetization in Co-Zn Ferrites at Low Temperatures.—N. M. Reĭnov & M. F. Stel'makh. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 342–344.) Experimental results of magnetic saturation of Co-Zn ferrites in the temperature range from the Curie point to 1·3°K are shown. No abnormal decrease in the magnetic saturation with the lowering of temperature was observed.

538.221 : 621.318.134 **3930**

Theory of the Spontaneous Magnetization of Ferrites.—E. I. Kondorski, A. S. Pakhomov & T. Shiklosh. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 334–341.) Mathematical analysis of the magnetization of ferromagnetic semiconductors at temperatures near 0°K.

538.221 : 621.318.134 **3931**

Cation Distribution and Magnetic Moment of Manganese Ferrite.—F. W. Harrison, W. P. Osmond & R. W. Teale. (*Phys. Rev.*, 1st June 1957, Vol. 106, No. 5, p. 865.)

538.221 : 621.318.134 **3932**

Molecular Field Fluctuation Effects in Mixed Nickel-Zinc Ferrites.—D. M. Grimes, S. Legvold & E. F. Westrum. (*Phys. Rev.*, 1st June 1957, Vol. 106, No. 5, pp. 866–867.) The thermal variations of the magnetic moment and heat capacity of some mixed Ni-Zn ferrites are discussed. Experimental data on the magnetic moments are shown.

538.221 : 621.318.134 : 534.13 **3933**

Acoustic Relaxations in Ferrite Single Crystals.—D. F. Gibbons. (*J. appl. Phys.*, July 1957, Vol. 28, No. 7, pp. 810–814.) A stress-induced relaxation near 40°K, with an activation energy of 0·03 ± 0·004 eV per electron jump, is common to all ferrites with divalent and trivalent ferrous ions on the octahedral sites. In Mn ferrite the activation energy of about 0·3 eV per electron jump depends upon the composition and homogeneity. In Mn and Mn-Zn ferrites a transformation occurs below 14°K; the transition temperature depends upon the composition.

538.221 : 621.318.134 : 537.322 **3934**

Thermoelectric Properties of Ferrites in the Range Close to Curie Temperature.—S. A. Varchenya & Ya. G. Dorfman. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 345–347.) Ni-Zn ferrites with specific resistance 10^6–10^7 Ω.cm were examined. The Peltier and Thomson effects showed similar magnetic anomalies as found in ferromagnetic metals.

538.221 : 621.318.134 : 538.569.4 **3935**

Effects of Ceramic Parameters on Microwave Properties of Nickel Ferrite.—S. L. Blum, J. E. Zneimer & H. Zlotnick. (*J. Amer. ceram. Soc.*, 1st May 1957, Vol. 40, No. 5, pp. 143–149.) A simple apparatus is described for measuring the magnetic loss as a function of magnetic field for ferrites at a frequency of 10 kMc/s. Tests on $NiFe_2O_4$ showed (*a*) it is possible to vary the width of the ferromagnetic resonance curve by adjusting the porosity of the ferrite; (*b*) the d.c. resistivity decreases with an increase in peak firing temperature. The range of resistivities possible in this material is 10–10^9 Ω. cm.

538.221 : 621.318.134 : 538.569.4 **3936**

Physical and Electrical Properties of a Nickel Ferrite as Affected by Compositional Changes.—S. L. Blum & J. E. Zneimer. (*J. Amer. ceram. Soc.*, 1st June 1957, Vol. 40, No. 6, pp. 208–211.) Experiments at 10 kMc/s on $Ni_{1-\alpha}Co_{\alpha}Fe_2O_4$, where α varies from zero to 0·05, show that the ferromagnetic resonance curve may be narrowed by suitable Co additions.

538.245 **3937**

Influence of Foreign Ions on the Critical Field Strength of an Antiferromagnetic.—K. F. Niessen. (*Philips Res. Rep.*, Aug. 1957, Vol. 12, No. 4, pp. 355–363.) See also 2843 of September.

538.245 : 621.396.822 **3938**

Frequency Spectrum of the Barkhausen Noise.—G. Biorci & D. Pescetti. (*J. appl. Phys.*, July 1957, Vol. 28, No. 7, pp. 777–780.) Measurements on iron, nickel and ferroxcube show the spectral density to be constant up to 1 kc/s and then to decrease rapidly. Agreement with theory is obtained if the single noise pulse is exponential with a time constant of 10^{-4} sec.

538.632 : 537.311.33 **3939**

The Hall Generator as a Quadripole.—F. Kuhrt & W. Hartel. (*Arch. Elektrotech.*, 12th Jan. 1957, Vol. 43, No. 1, pp. 1–15.) The quadripole representation of a Hall-effect device is analysed, in particular, the dependence of the characteristic impedance on the magnetic field and external circuit conditions. Three types of matching conditions are defined: (*a*) for achieving linearity, (*b*) for maximum power output, and (*c*) for maximum efficiency. The efficiency is calculated from the quadripole equations, and evaluated, with the other characteristics, for a given InAs Hall element.

548.0 : 53 **3940**

Electrical, Optical and Elastic Properties of Diamond Type Crystals: Part 1.—V. S. Mashkevich & K. B. Tolpygo. (*Zh. eksp. teor. Fiz.*, March 1957, Vol. 32, No. 3, pp. 520–525.) The energy contained in a homopolar crystal is represented as a function of displacements and dipole movements of the atoms.

549.514.51 **3941**

Electrical Conductivity of Fused Quartz.—J. Cohen. (*J. appl. Phys.*, July 1957, Vol. 28, No. 7, pp. 795–800.) Measurements made in vacuo at temperatures from 600° to 1 400°C show that one specimen obeyed Ohm's law while another did not. The variation in behaviour is attributed to differences in the impurity contents.

549.514.51 : 534.133 **3942**

On the Angle between Wave Front and Displacement of Plane Acoustic Waves in Quartz.—B. van der Veen. (*Philips Res. Rep.*, Aug. 1957, Vol. 12, No. 4, pp. 273–280.) Development of the theory of piezoelectric vibrations for nonrectangular X-cut crystals free from unwanted flexural modes of vibration.

621.315.61 : 537.529 **3943**

Statistical Delay of Electrical Breakdown of Solid Dielectrics.—E. A. Konorova. (*Zh. eksp. teor. Fiz.*, March 1957, Vol. 32, No. 3, pp. 603–604.) Tests were made to determine the delay of electrical breakdown of samples of mica 2–$10\,\mu$ and glass 3–$10\,\mu$ thick. The duration of the voltage application to obtain punctures varied from 10^{-2} to 5×10^{-8} sec. Results are shown graphically.

621.319.4-762 **3944**

Tropicalization—Results of Experiments on Sealing Capacitors.—C. V. Ganapathy, R. Krishnan & T. V. Ramamurti. (*J. Instn Telecommun. Engrs, India*, March 1957, Vol. 3, No. 2, pp. 116–122.)

537.311.33 **3945**

Report of the Meeting on Semiconductors held by the Physical Society, in collaboration with British Thomson-Houston Ltd., Rugby, in April 1956. [Book Review]—Publishers: The Physical Society, London, 1957, 153 pp., 20s. (*Nature, Lond.*, 6th July 1957, Vol. 180, No. 4575, pp. 25–26.) The text of 22 of the 23 papers read is given.

MATHEMATICS

517 : 518.2 **3946**

Laguerre Functions: Tables and Properties.—J. W. Head & W. P. Wilson. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, p. 543.) Discussion on 518 of February.

517.512 **3947**

Table of the Fresnel Integral to Six Decimal Places. [Book Review]—T. Pearcey. Publishers: Cambridge University Press, 1956, 63 pp., 12s. 6d. (*Nature, Lond.*, 6th July 1957, Vol. 180, No. 4575, p. 6.)

MEASUREMENTS AND TEST GEAR

53.082 **3948**

Instrument Transducers.—J. Thomson. (*J. sci. Instrum.*, June 1957, Vol. 34, No. 6, pp. 217–221.) A survey of available means for converting energy from one form to another, and their application to automatic manufacturing processes.

621.3.018.41(083.74) + 529.786] **3949**
: 538.569.4

Frequency Shift in Ammonia Absorption due to Self-Broadening.—K. Matsuura, Y. Sugiura & G. M. Hatoyama. (*J. phys. Soc. Japan*, March 1957, Vol. 12, No. 3, p. 314.) Note on a shift in resonance frequency of the ammonia line with pressure near 23 870 Mc/s. See also 2858 of September.

621.314.7.001.4 **3950**

Measuring Parameters of Junction Transistors.—R. W. Hendrick, Jr. (*Electronics*, 1st Aug. 1957, Vol. 30, No. 8, pp. 174–176.) The instrument measures dynamic ground-emitter characteristics of *p-n-p* or *n-p-n* transistors at any static collector current from 0·15 to 15 mA.

621.314.7.012 : 621.317.755 **3951**

Investigation of Transistor Characteristics by means of a Cathode-Ray Curve Tracer.—A. M. Bonch-Bruevich & U. B. Soltamov. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 311–316.) Description of circuits with photographs of characteristics displayed on the c.r. tube screen.

621.317.18 : 621.373.421.1 **3952**

Simple Grid-Dip Oscillator.—R. Ireland & V. Penfold. (*Short Wave Mag.*, March 1957, Vol. 15, No. 1, pp. 16–18.) Constructional details of a unit covering a wide frequency range.

621.317.3.029.64 : 621.396.822 **3953**

Improved Microwave Noise Measurements using Ferrites.—C. H. Mayer. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. MTT-4, No. 1, pp. 24–28. Abstract, *Proc. Inst. Radio Engrs*, April 1956, Vol. 44, No. 4, p. 581.)

621.317.32 **3954**

Method of Measurement of Potential Distribution on the Surface of a Dielectric.—V. Ya. Upatov. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 184–192.) A pulse method for measuring the potential distribution on a non-uniformly charged dielectric is described. A fine graticule placed on the surface of the dielectric is scanned by an electron beam to produce positive or negative pulses according to the charge present. The experimental circuits and some results are given.

621.317.321 : 537.311.33 **3955**

New Modification of the Capacitance Method of Measuring Potential Difference and its Application to the Study of Contact Potentials of Semiconductors.—B. F. Bogolyubov. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 323–327.) The effect of illumination and pressure on the potential difference in metallic Se contacts is investigated. For a pressure $P \leqslant 5 \times 10^{-1}$ mm Hg this contact potential does not depend on illumination and remains approximately constant, but for $P \geqslant 2 \times 10^{-5}$ mm Hg the contact potential varies linearly with weak illumination. Results for seven samples are tabulated.

621.317.328 **3956**

A New Type of V.H.F. Field Intensity Meter using a Loop Antenna.—H. Koseki. (*J. Radio Res. Labs, Japan*, April 1957), Vol. 4, No. 16, pp. 123–125.) Calibration is achieved by feeding a comparison voltage, which can be measured, through a coupling circuit to the loop and the receiver. Errors of ± ½ dB over the range 15–100 Mc/s are quoted.

621.317.33 : 621.3.035.4 **3957**

A New Device for Conductivity Measurement by means of Radio-Frequency Currents and Non-immersed Electrodes.—G. Barbi. (*Ricerca sci.*, May 1957, Vol. 27, No. 5, pp. 1438–1447.) Description of apparatus for measuring the conductivity of electrolytic solutions using a frequency of about 9 Mc/s.

621.317.33.029.6 : 621.317.755 **3958**

An Automatic Smith-Diagram Display Unit for Use at Low Power Levels.—H. V. Shurmer. (*Proc. Instn elect. Engrs*, Part B, Sept. 1957, Vol. 104, No. 17, pp. 507–510.) The method, by which a Smith diagram is directly displayed on a c.r. tube, may be applied to microwave transmission systems generally.

621.317.335.3.029.63/.64 **3959**
:538.569.2.047

The Determination of Dielectric Constants particularly of Biological Substances in the Range of Decimetre and Centimetre Waves.—B. Rajewsky & A. Redhardt. (*Arch. elekt. Übertragung*, April 1957, Vol. 11, No. 4, pp. 163–166.) A resonance method of measurement such as that used by Schwan & Kamli (813 of 1954) is discussed and formulae are derived facilitating the evaluation of results.

621.317.335.3.029.64 **3960**

A Method of Determining the Dipole Moment and Relaxation Time from Microwave Measurements.—K. V. G. Krishna. (*Trans. Faraday Soc.*, June 1957, Vol. 53, Part 6, pp. 767–770.) The method is applied to dilute solutions of polar substances in nonpolar solvents, and is based on measuring the dielectric constant and loss as a function of concentration.

621.317.336 **3961**

The Accuracy of Impedance Measurements by means of Long Lines.—R. M. Dombrugov. (*Radiotekhnika, Moscow*, June 1956, Vol. 11, No. 6, pp. 66–70.) A formula for correcting the errors due to line losses is derived and a number of curves for facilitating calculations are plotted. The accuracy so obtained is estimated.

621.317.34 **3962**

Self-Calibrating Method of Measuring Insertion Ratio.—(*Tech. News Bull. nat. Bur. Stand.*, Sept. 1957, Vol. 41, No. 9, pp. 132–133.) Description of a null method for the determination of phase angle and insertion loss of a network. The circuit illustrated has three parallel legs connected between a r.f. generator and a monitor. Two of the legs contain piston attenuators, one in series with a phase shifter. The third leg contains the unknown network in series with a second phase shifter which is used for self-calibration.

621.317.34.029.64 : 621.372.5 **3963**
:621.396.822

Measurements on Noisy Fourpoles at Microwave Frequencies.—M. T. Vlaardingerbroeck, K. S. Knol & P. A. H. Hart. (*Philips Res. Rep.*, Aug. 1957, Vol. 12, No. 4, pp. 323–332.) A new method of measuring the characteristic noise quantities of noisy linear fourpoles is described. Applied to microwave frequencies this method is very simple when the fourpole is matched to the characteristic impedance of the waveguide, which can always be achieved. The method is applied to a microwave triode amplifier.

621.317.342 : 621.396.65 **3964**

Sensitive Group Delay Meters.—R. Magnusson. (*Ericsson Tech.*, 1957, Vol. 13, No. 1, pp. 109–142.) The requirements of an instrument for measuring the group delay of wide-band radio-link i.f. amplifiers are stated. A critical survey of existing methods of measuring group delay is given and a delay meter of very high sensitivity is described.

621.317.361.029.64 : 538.569.4 **3965**

A Frequency Comparator using Electron and Proton Resonance in a Common Magnetic Field.—O. Nourse. (*Nature, Lond.*, 27th July 1957, Vol. 180, No. 4578, p. 192.) An outline of a method of measuring microwave frequencies using electron and proton paramagnetic resonances in a common magnetic field. With the ratio of the two resonance frequencies ≈ 658·5 the lower frequency can be determined accurately by conventional methods.

621.317.382.029.64 : 621.3.089.6 **3966**

Measurements of Efficiency of Bolometer and Thermistor Mounts by Impedance Methods.—J. A. Lane. (*Proc. Instn elect. Engrs*, Part B, Sept. 1957, Vol. 104, No. 17, pp. 485–486.) The method of calibrating milliwattmeters for microwave frequencies by measuring impedances is compared with the method of calibrating them against standard equipment. The impedance method may be satisfactory for bolometers but is unsatisfactory at present for thermistors.

621.317.733.011.22 : 621.314.58 **3967**
: 621.375.13

An Inductronic Double Bridge.—J. H. Miller. (*Elect. Engng, N.Y.*, April 1957, Vol. 76, No. 4, pp. 300–302.) Low resistances can be measured with accuracy, speed and simplicity of operation using a system of two 'inductronic' d.c. amplifiers based on a principle applied in the induction galvanometer described by Gilbert (3666 of 1953).

621.317.733.3 : 621.3.011.21 **3968**

A Precision Dual Bridge for the Standardization of Admittance at Very High Frequencies.—D. Woods. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 506–521.) A detailed description of a twin-T dual bridge for use in the band 3–300 Mc/s. The inaccuracy in either component of a complex admittance is 0·2% or less at 200 Mc/s. The calibration is based on a range of coaxial susceptance standards whose parameters are calculated from measurements of length and time.

621.317.755 + 621.373.43 **3969**

High-Power Pulse Generators.—Bruijning. (See 3787.)

621.317.755 **3970**

A Cathode-Ray-Tube Oscilloscope for Use in Millimicrosecond Pulse Techniques.—J. W. Armitage, G. Gaskin & K. Phillips. (*Electronic Engng*, Aug. 1957, Vol. 29, No. 354, pp. 364–367.) The time-base employs a thyratron trigger and a hard-valve sweep circuit with a continuously variable sweep speed from 3 μs down to 15 mμs with a scan of approximately 2 kV. A c.r. tube with side-arm connections is used. Full design details are given.

621.317.784.029.64 **3971**

An Instrument for the Absolute Measurement of Low-Level Microwave Power in the 3-cm Band.—A. L. Cullen & H. A. French. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 456–464.) The instrument consists of a thin metallic rod suspended inside a rectangular H_{011} cavity. The oscillating system receives periodic impulses from the interaction between the e.m. field and the rod, the source being switched on and off periodically. The estimated error in the range 5–100 mW or more is not greater than ±2%.

621.317.79 : 537.56 **3972**

An R.F. Probe Technique for the Measurement of Plasma Electron Concentrations in the Presence of Negative Ions.—T. H. Y. Yeung & J. Sayers. (*Proc. phys. Soc.*, 1st July 1957, Vol. 70, No. 451B, pp. 663–668.)

621.317.794 **3973**

An Evaporated Gold Bolometer.—E. Archbold. (*J. sci. Instrum.*, June 1957, Vol. 34, No. 6, pp. 240–242.) Description of an infrared detector with a sensitivity of $1\cdot5$ V/W; minimum detectable energy is $3\cdot6 \times 10^{-10}$ W, measured at 10 c/s.

621.317.794 : 537.311.33 **3974**

Some Problems in the Application of Semiconductor Bolometers. — A. M. Bonch-Bruevich & Ya. A. Imas. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 317–322.) The instrument described is used for the investigation of fast transients. By means of a compensating *RC* circuit various time constants are obtained. Such a compensating circuit reduces the threshold sensitivity of the device to a lesser extent than the lowering of bolometer inertia by an increase of its heat radiation.

621.317.794 : 621.396.822 **3975**

The Theoretical Sensitivity of the Dicke Radiometer.—L. D. Strom. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1291–1292.) A new analysis of the Dicke circuit (475 of 1947) has been made which shows that the sensitivity is independent of the detector characteristics.

621.317.794.029.64 **3976**

The Measurement of Thermal and Similar Radiations at Millimetre Wavelengths.—G. R. Nicoll. (*Proc. Instn elect. Engrs*, Part B, Sept. 1957, Vol. 104, No. 17, pp. 519–527.) "The measurement of thermal and similar noise radiations at millimetre wavelengths is discussed. It is shown how this type of measurement is applied to radiation from gas discharges, flames and crystal diodes, and how it is used in certain studies of the atmosphere. Two types of measuring instrument are compared."

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534-8 **3977**

Cleaning by Ultrasonics.—L. Atherton. (*Brit. Commun. Electronics*, March 1957, Vol. 4, No. 3, pp. 138–144.) Small engineering components are suspended in a tank of cleaning solvent in which ultrasonic vibrations are induced by a $BaTiO_3$ transducer operating at 1 Mc/s.

621-57 : 537.228.4 **3978**

Development of the Electrostatic Clutch.—C. J. Fitch. (*IBM J. Res. Developm.*, Jan. 1957, Vol. 1, No. 1, pp. 2–7.) See also 3253 of October.

621.365.5 **3979**

Electronic Heating and Automation.—M. T. Elvy. (*J. Brit. Instn Radio Engrs*, Aug. 1957, Vol. 17, No. 8, pp. 443–462.) A survey of principles of induction and dielectric heating and their application to some industrial processes.

621.384.6 **3980**

Electron Model Fixed-Field Alternating-Gradient Accelerator.—F. T. Cole, R. O. Haxby, L. W. Jones, C. H. Pruett & K. M. Terwilliger. (*Rev. sci. Instrum.*, June 1957, Vol. 28, No. 6, pp. 403–420.) Detailed description of the design, construction and performance of a radial-sector model accelerating electrons from 25 to 400 keV.

621.384.611 **3981**

New Possibilities of Increasing the Efficiency of Accelerators of Charged Particles.—E. M. Moroz. (*C. R. Acad. Sci. U.R.S.S.*, 1st July 1957, Vol. 115, No. 1, pp. 78–79. In Russian.) An improved magnet system is briefly described which consists of three or more sectors producing a uniform magnetic field. See also 3503 of 1956.

621.384.622.2 **3982**

The Possibility of Focusing in a Linear Accelerator by means of a Travelling Wave.—V. S. Tkalich. (*Zh. eksp. teor. Fiz.*, March 1957, Vol. 32, No. 3, pp. 625–626.) Theoretical investigation of the simultaneous radial and phase stability of heavy particles obtained by means of the focusing effect of a travelling wave.

621.387.424 **3983**

Geiger-Müller Counter Tubes.—J. Sharpe. (*Brit. Commun. Electronics*, March 1957, Vol. 4, No. 3, pp. 150–157.) Includes a table of representative British types.

621.398 : 621.3.087.9 **3984**

Automatic Data Plotter for F.M./F.M. Telemetering.—H. B. Riblet. (*Electronics*, 1st Aug. 1957, Vol. 30, No. 8, pp. 182–187.) Apparatus for plotting results derived linearly or nonlinearly from telemetry data with any scale factor.

PROPAGATION OF WAVES

621.396.11 **3985**

Wave Propagation over an Irregular Terrain: Part 1.—K. Furutsu. (*J. Radio Res. Labs, Japan*, April 1957, Vol. 4, No. 16, pp. 135–153.) A mathematical treatment of a model earth in which there are simultaneous discontinuities in the electrical properties and the radius of the earth's surface.

621.396.11 : 523.75 **3986**

On the Disturbances of Radio Propagation along the North Polar Route.—Y. Hakura. (*J. Radio Res. Labs, Japan*, April 1957, Vol. 4, No. 16, pp. 101–110.) An analysis of disturbances on the WWV-Hiraiso route. Storms are divided into two main types, sudden-commencement and M-region, but each of these may be recurrent or nonrecurrent. The four types are discussed in terms of solar activity.

621.396.11 : 538.566 **3987**

Fundamental Radio Scatter Propagation Theory.—E. C. S. Megaw. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 441–455.) A detailed theoretical treatment of scatter propagation beyond the horizon. The spectral density of refractive index fluctuation is derived from the universal equilibrium theory of turbulence, and the results are applied to the problem of fluctuations in the free-space paths for both light and radio waves. The predictions are compared with experiment, and the variation of the intensity of refractive index fluctuations with height is derived. The detailed treatment of radio scatter propagation includes a full analysis of the influence of the geometry of the scattering volume on the received field strength. The form of the scattering cross-section implied in the results is compatible with those obtained in alternative treatments based on idealized models. 29 references.

621.396.11 : 551.510.53 **3988**

The Role of Stratospheric Scattering in Radio Communication.—H. G. Booker & W. E. Gordon. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1223–1227.) The mixing-in-gradient hypothesis is applied to the stratosphere and the power scattered to a receiver is calculated. The characteristics of this means of propagation relative to its role in communications are discussed and comparisons are made between observations and theoretical predictions.

621.396.11 : 551.510.535 **3989**

Application of the Generalized Magneto-Ionic Theory to the Propagation of Radio Waves at the Magnetic-Dip Poles of the Earth.—C. L. Bai. (*J. atmos. terr. Phys.*, 1957, Vol. 11, No. 1, pp. 31–35.) Booker's magneto-ionic theory is used to evaluate the reflection levels, at the dip poles, of the ordinary and extraordinary rays at various angles of incidence and for frequencies above and below the gyro frequency.

621.396.11 : 551.510.535 **3990**

Oblique Ray Paths in the Ionosphere.—J. Haselgrove. (*Proc. phys. Soc.*, 1st July 1957, Vol. 70, No. 451B, pp. 653–662.) Ray paths are calculated using an electronic digital computer, for propagation in the magnetic meridian plane of the ordinary ray over a flat earth, with a parabolic ionosphere. The computed range and equivalent path for various angles of incidence are compared with those given by simple no-field theory.

621.396.11 : 551.594.6 **3991**

Heavy-Ion Effects in Audio-Frequency Radio Propagation.—C. O. Hines. (*J. atmos. terr. Phys.*, 1957, Vol. 11, No. 1, pp. 36–42.) Propagation of whistlers may be due to ions as well as electrons, whereas the previous theory includes only electrons. The effect is to allow propagation in all directions and to introduce transverse modes with the dispersion in the opposite sense to that for the longitudinal ones.

621.396.11.029.6 **3992**

Calculation of the Field Strength in Shadow and Half-Shadow Regions in the Case of Ultra-Short Waves Travelling along a Smooth Spherical Surface of the Earth.—A. I. Kalinin. (*Radiotekhnika, Moscow*, June 1956, Vol. 11, No. 6, pp. 43–49.) An approximation method is described and its limits of validity are established.

621.396.11.029.62 **3993**

Results of Experiments on V.H.F. Overland Propagation beyond the Radio Horizon.—S. Niwa, S. Watanabe, H. Saito, T. Sasaki, Y. Fujii & M. Minowa. (*J. Radio Res. Labs, Japan*, April 1957, Vol. 4, No. 16, pp. 111–122.) Frequencies near 150 Mc/s were used over a 123-km path in Japan from March to August 1956. The results are presented in statistical and graphical form.

621.396.812.029.6 **3994**

Meteorological Influences on the Hourly Median Field Strength of Ultra Short Waves in the Diffraction Region.—K. Tao. (*J. Radio Res. Labs, Japan*, April 1957, Vol. 4, No. 16, pp. 155–254.) Statistics of the vertical gradient of atmospheric refractive index over Japan are presented and their effect on v.h.f. propagation discussed. Observed seasonal variations in field strength are correlated with abnormal distributions of refractive index, and reflections from elevated discontinuities are shown to cause high field strength at night. Some 80 references.

RECEPTION

621.396.621 : 621.396.666 **3995**

Theoretical Investigations of some Diversity Methods.—E. Henze. (*Arch. elekt. Übertragung*, May 1957, Vol. 11, No. 5, pp. 183–194.) General equations are derived for the characteristics of signals received by means of various aerial and receiver diversity methods. Statistically correlated and uncorrelated signals are considered, and the effect of noise is taken into account.

621.396.621 : 621.396.822.1 **3996**

The Efficiency of Diversity Reception in the Presence of Interference from Radio Stations Operating at Adjacent Frequencies.—V. M. Rozov. (*Radiotekhnika, Moscow*, July 1956, Vol. 11, No. 7, pp. 14–25.) The average percentage distortion of telegraph signals when diversity on two aerials is used is compared with the corresponding figure for ordinary reception. The analysis is carried out for a long-range short-wave radio link.

621.396.621.029.62 : 621.372.632 **3997**

Design Considerations of 50-Mc/s Converters.—C. F. Hadlock. (*QST*, March 1957, Vol. 41, No. 3, pp. 17–20.) The minimizing of cross-modulation and overloading of the first stage from adjacent-channel interference is discussed in relation to the overall noise figure. A circuit design is presented.

621.396.621.57 : 621.314.7 **3998**

Transistor Superregenerative Detection.—W. F. Chow. (*Trans. Inst. Radio Engrs*, March 1956, Vol. CT-3, No. 1, pp. 58–61. Abstract, *Proc. Inst. Radio Engrs*, July 1956, Vol. 44, No. 7, p. 953.)

621.396.82 **3999**

Minimum Signal-to-Interference Ratio Required for Broadcasting.—S. C. Mazumdar, G. V. Padhye & W. V. B. Ramalingam. (*J. Instn Telecommun. Engrs, India*, March 1957, Vol. 3, No. 2, pp. 110–115.) A determination from listening tests (750 recordings and 12 000 opinions) of the protection required for a speech-modulated broadcast signal against interference from speech, music and c.w. morse.

STATIONS AND COMMUNICATION SYSTEMS

621.376 : 621.396.4 **4000**

Single-Sideband Modulation by means of Phase-Shift Systems.—B. B. Shtein. (*Radiotekhnika, Moscow*, June 1956, Vol. 11, No. 6, pp. 13–26.) The separation of a sideband by means of three-phase modulation is considered. Experiments show that the second sideband can be suppressed by more than 40 dB.

621.376.332 : 621.3.018.78 **4001**

Discriminator Distortion in Frequency-Modulation Systems.—R. G. Medhurst & H. D. Hyamson. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 357–365.) Theory given earlier [2503 of 1954 (Medhurst)] is extended to cover discriminator networks whose characteristics exhibit small departures from ideal forms. Single-tone and noise-band modulations are treated. Two numerical examples are given.

621.376.56 : 621.396.8 **4002**

Some Optimal Signals for Time Measurement.—H. Sherman. (*Trans. Inst. Radio Engrs*, March 1956, Vol. IT-2, No. 1, pp. 24–28. Abstract, *Proc. Inst. Radio Engrs*, July 1956, Vol. 44, No. 7, p. 956.) Discussion of the optimum code for determination of the phase of a signal in the presence of Gaussian noise.

621.39 **4003**

Communications and the Future.—G. Radley. (*J. Electronics Control*, Aug. 1957, Vol. 3, No. 2, pp. 211–217.) A survey of current developments with consideration of economic factors. The introduction of electronic exchanges and nation-wide dialling for the telephone service, and links for data transmission are discussed.

621.39.001.11 : 016 **4004**

A Bibliography of Information Theory (Communication Theory—Cybernetics).—F. L. Stumpers. (*Trans. Inst. Radio Engrs*, Sept. 1955, Vol. IT-1, No. 2, pp. 31–47.) Supplement to previous list (see 1566 of 1954).

621.396.41 : 621.376.3 : 621.396.813 **4005**

Intermodulation Distortion due to Fading in Frequency-Modulation Frequency-Division Multiplex Trunk Radio Systems.—R. G. Medhurst & M. Hodgkinson. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 475–480.) A theoretical study, with numerical results, of the dependence of distortion level on the characteristics of the echoes responsible for the fade. See also 1867 of 1956 (Medhurst & Small).

621.396.41.029.6 : 621.396.822 **4006**

Noise Considerations on Toll Telephone Microwave Radio Systems.—T. A. Comebellick & M. E. Ferguson. (*Elect. Engng, N.Y.*, April 1957, Vol. 76, No. 4, pp. 314–317.) Performance of microwave radio equipment is analysed to determine whether it will conform to overall noise requirements of the telephone network.

621.396.65.029.64 **4007**

Crosstalk Measurements between Antennae on the Johannesburg-Pretoria Microwave Radio System.—D. Davidson & B. P. Mackenzie. (*Trans. S. Afr. Inst. elect. Engrs*, March 1957, Vol. 48, Part 3, pp. 93–111. Discussion, pp. 111–119.) Detailed report of an investigation of excessive crosstalk occurring in a two-frequency system operating in the 4-kMc/s band. Measurement methods including heterodyne and sweep techniques are described, and the effectiveness of aerial screening and cross-polarization in eliminating reflection effects is discussed.

621.396.933 **4008**

Second Annual Symposium on Aeronautical Communications.—J. W. Worthington, Jr. (*Trans. Inst. Radio Engrs*, March 1957, Vol. CS-5, No. 1, pp. 3–130.) The text is given of 17 papers presented at a symposium held at Utica, New York, in October 1956. Abstracts of most of these papers are given in *Proc. Inst. Radio Engrs*, June 1957, Vol. 45, No. 6, pp. 895–896.

SUBSIDIARY APPARATUS

621.316.722.078.3 **4009**

A Voltage Stabilizer Principle.—C. Billington & E. Chakanovskis. (*Electronic Engng*, Aug. 1957, Vol. 29, No. 354, pp. 374–376.) Positive feedback eliminates the need for an auxiliary negative supply in controlling the output down to zero volts with a series-valve stabilizer arrangement.

621.316.722.078.3 **4010**

A Discussion of Series Valves for Small D.C. Voltage Stabilizers.—C. Billington. (*Electronic Engng*, Aug. 1957, Vol. 29, No. 354, pp. 377–379.) "A graphical method of assessing the performance of a series valve is presented. On this basis fifteen valve types are compared, and some valves not normally used in this application are shown to have unsuspected advantages."

621.316.722.1 **4011**

Stabilization of A.C. Supplies.—O. E. Dzierzynski. (*Wireless World*, Oct. 1957, Vol. 63, No. 10, pp. 491–496.) A comprehensive, comparative review of methods of voltage control with practical examples of a number of circuits and techniques.

621.316.79 : 621.365.41 **4012**

Simple Constant-Temperature Oven and Control System.—G. R. Gunther-Mohr & S. Triebwasser. (*IBM J. Res. Develpm.*, Jan. 1957, Vol. 1, No. 1, pp. 84–89.) A thermocouple-monitored system consisting of an oven, a stable reference source and a chopper-amplifier controller unit is described. A stable and uniform temperature, ± 0·1°C from 200° to 1 050°C is maintained in a cylindrical region 5 cm in diameter and 12 cm long.

621.316.925 **4013**

An H.T. Overload Cut-Out Circuit.—J. D. Ralphs. (*Electronic Engng*, Aug. 1957, Vol. 29, No. 354, pp. 398–400.) Description of a circuit designed in conjunction with a stabilized h.v. supply for laboratory work.

TELEVISION AND PHOTOTELEGRAPHY

621.397.26 : 621.396.82 **4014**

Freedom from Interference and the Efficiency of Radio Phototelegraphy Systems in the Presence of Fluctuation-Type Interference.—A. G. Zyuko. (*Radiotekhnika, Moscow*, Aug. 1956, Vol. 11, No. 8, pp. 14–24.) Four different types of modulation system are compared.

621.397.3 : 654.171 **4015**

Statistical Methods of Phototelegraphy Transmission.—R. R. Vasil'ev. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 136–143.) Two methods of scanning are described whereby the speed of phototelegraphic transmission can be increased. In one, signals are transmitted in binary form, in the other an image is reproduced on a c.r. tube and photographed.

621.397.33 **4016**

A Variable-Velocity Scanner for Magnetic Deflection of a Scanning Spot.—M. P. Beddoes. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 481–488.) A description of a magnetic scanner with negative feedback. Satisfactory operation is obtained for repetitive scanning rates up to 10^4/sec with a maximum displacement error of no more than 0·2%.

621.397.5 : 535.623 **4017**

Subjective Colour for Television?—C. E. M. Hansel. (*Wireless World*, Oct. 1957, Vol. 63, No. 10, pp. 508–509.) An explanation of colour impressions observed on monochrome television in terms of the 'Helmholtz top' experiment.

621.397.5 : 621.395.625.3 **4018**

Video Tape Recorder uses Revolving Heads.—R. H. Snyder. (*Electronics*, 1st Aug. 1957, Vol. 30, No. 8, pp. 138–144.) Low tape speed and extended high-frequency response are achieved by revolving four magnetic recording heads transversely across the tape, which moves only fast enough to prevent over-lapping. For another system of rotating pick-up heads, see 2952 of 1956 (Springer).

621.397.5 : 718.5 **4019**

A 16-mm Television Recording Channel.—M. E. Pemberton. (*Marconi Rev.*, 1st & 2nd Quarters 1957, Vol. 20, Nos. 124 & 125, pp. 4–22 & 39–50.) Details are given of a system operating at 625/405 lines with 50 fields/s or at 525 lines with 60 fields/s. In Part 1 the overall channel and the recording monitor are described; Part 2 deals with the fast pull-down camera and driving unit, the flywheel-synchronizing panel and the power supplies.

621.397.6 **4020**

Television Links for an Outside Broadcast from a Vessel on Lake Geneva.—F. Grandchamp. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st June 1957, Vol. 35, No. 6, pp. 243–248. In French.)

621.397.6 : 535.623 **4021**

Sync Generator for Dot-Interlace TV.—F. T. Thompson. (*Electronics*, 1st Aug. 1957, Vol. 30, No. 8, pp. 170–173.) "Accurately phased horizontal and vertical synchronization pulses are obtained by sampling pulses from frequency-divided chains to obtain output corresponding in phase to half-cycle of high-frequency signal. Though design is for 14·7-kc/s line and 60-c/s field frequencies, with 2·47-Mc/s reference frequency, technique is directly applicable to N.T.S.C. colour systems."

621.397.6 : 621.396.73 **4022**

An Improved 'Roving Eye'.—T. Worswick & G. W. H. Larkby. (*B.B.C. Engng Div. Monographs*, April 1957, No. 12, pp. 5–18.) Details are given of a television camera vehicle which can transmit pictures and sound while moving or stationary. Two cameras and associated equipment, power supplies, radio-link apparatus and aerials are included in a compact self-contained unit particularly suitable for short outside broadcasts.

621.397.611 **4023**

Motion Minimizes Image-Orthicon Burn-In.—J. T. Wilner. (*Electronics*, 1st Aug. 1957, Vol. 30, No. 8, pp. 180–181.) The image orthicon tends to retain a previous camera shot. This effect can be greatly reduced by oscillating slowly the lens board of the television camera.

621.397.611 **4024**

Television Camera with Storage Tube having a Curved Characteristic.—W. Dillenburger. (*Elektronische Rundschau*, May & June 1957, Vol. 11, Nos. 5 & 6, pp. 143–146 & 174–178.) The design and operation of such a camera system are discussed with particular reference to the vidicon tube.

621.397.611.2 : 621.317.351 **4025**

Contribution to the Technique of Measurements on Television-Camera Pre-amplifiers. — W. Dillenburger. (*Frequenz*, May 1957, Vol. 11, No. 5, pp. 137–142. Correction, *ibid.*, June 1957, Vol. 11, No. 6, p. 191.) Methods for obtaining the frequency characteristics of the pre-amplifier without removing the camera tube are outlined.

621.397.8 **4026**

The Reception of Crystal Palace Transmissions in Australia.—N. Burton. (*R.S.G.B. Bull.*, March 1957, Vol. 32, No. 9, pp. 401–402.)

621.397.8 **4027**

Measurement of Service Area for Television Broadcasting.—(*Tech. News Bull. nat. Bur. Stand.*, Aug. 1957, Vol. 41, No. 8, pp. 113–115.) Currently field-strength contours are determined using recorders in moving road vehicles. It is not always possible to use a 30-ft aerial height with such vehicles and extrapolated measurements made with lower aerials are not reliable. Sample measurements at fixed locations are now considered to be more satisfactory.

621.397.8 : 535.623 **4028**

Level Clamping and some Interference Effects in Colour Television Transmission Systems.—W. Dillenburger. (*Arch. elekt. Übertragung*, May 1957, Vol. 11, No. 5, pp. 195–213.) Equipment is described which was developed for investigating the effects of level variations, carrier interference and detuning on picture quality in the 3-channel and N.T.S.C. systems. Results are discussed and are illustrated by colour photographs.

621.397.813 : 778.5 **4029**

The Evaluation of Picture Quality in Television.—N. R. Phelp. (*Marconi Rev.*, 1st Quarter 1957, Vol. 20, No. 124, pp. 23–32.) The technique described in 1127 of 1952 (Jesty & Phelp) is applied to assess the performance of a television recording channel.

621.397.828 **4030**

Problems in Metropolitan TV Reception.—S. Holzman. (*Radio & Telev. News*, March 1957, Vol. 57, No. 3, pp. 38–39.) Suitable remedies for multipath signals and interference are suggested.

TRANSMISSION

621.396.61 **4031**

Single-Sideband Exciter.—J. Headland. (*Short Wave Mag.*, March 1957, Vol. 15, No. 1, pp. 8–15.) Practical details of design and construction of a filter-type s.s.b. unit based on a 93-kc/s crystal oscillator.

621.396.61 **4032**

A 3-Band 90-Watt Transmitter.—C. C. Tiemeyer. (*QST*, March 1957, Vol. 41, No. 3, pp. 35–37.) The transmitter operates in the 160, 80 and 40-m bands.

621.396.61 : 621.396.662 **4033**

High-Power Transmitter Tuning Devices—the Mechanical and Electrical Problems.—V. O. Stokes. (*Brit. Commun. Electronics*, March 1957, Vol. 4, No. 3, pp. 158–162.) Transmitters operating in the 4–27·5-Mc/s band are considered. Tuning and coupling systems used in a 30-kW communication transmitter and a 100-kW broadcasting transmitter are detailed.

VALVES AND THERMIONICS

621.314 : 537.312.8 : 538.63 **4034**

The Gaussistor, a Solid-State Electronic Valve.—M. Green. (*Trans. Inst. Radio Engrs*, July 1956, Vol. ED-3, No. 3, pp. 133–141. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, p. 1642.)

621.314.63 : 621.316.82 **4035**

Some Characteristics of Metallic Varistors.—Holbrook & Dulmage. (See 3764.)

621.314.632 : 537.311.33 : 621.372.632 **4036**

Theory and Operation of Crystal Diodes as Mixers.—G. C. Messenger & C. T. McCoy. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1269–1283.) The electrical parameters of a crystal diode are quantitatively related to its fundamental physical properties and the effects of these parameters on conversion loss at u.h.f. and microwave frequencies are discussed. A figure of merit by which semiconductor materials may be compared for their mixer sensitivity is suggested and it is shown that *n*-type Ge is a better mixer material than *p*-type Si. The relation between conversion loss and noise temperature, and receiver noise are discussed. The application of the theory to the design of mixers is demonstrated.

621.314.632 : 546.289 **4037**

Investigation of the Input Impedance, and the Experimental Checking of the Equivalent Circuit of Germanium Detectors in the Frequency Range 1–10 Mc/s.—N. E. Skvortsova. (*Radiotekhnika i Elektronika*, March 1957, Vol. 2, No. 3, pp. 296–310.)

621.314.7 : 621.314.63 **4038**

A Developmental Intrinsic-Barrier Transistor.—R. M. Warner, Jr, & W. C. Hittinger. (*Trans. Inst. Radio Engrs*, July 1956, Vol. ED-3, No. 3, pp. 157–160. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, p. 1642.) See also 2133 of 1955 (Hittinger et al.).

621.314.7 **4039**

A New Higher-Ambient Transistor.—J. J. Bowe. (*Trans. Inst. Radio Engrs*, July 1956, Vol. ED-3, No. 3, pp. 121–123. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, p. 1642.)

621.314.7 **4040**

Design, Construction and High-Frequency Performance of Drift Transistors.—A. L. Kestenbaum & N. H. Ditrick. (*RCA Rev.*, March 1957, Vol. 18, No. 1, pp. 12–23.) The electrical characteristics of developmental drift transistors are related to their physical structure, which is described.

621.314.7 **4041**

Transistor Characteristics at Very Low Temperatures.—S. Uda. (*J. Instn Telecommun. Engrs, India*, March 1957, Vol. 3, No. 2, pp. 97–109.) A comparison of terminal d.c. characteristic curves of common-base *p-n-p* junction transistors measured at liquid-helium, liquid-air and room temperatures. Gain is decreased at the lowest temperatures.

621.314.7 **4042**

Effect of Nonlinear Collector Capacitance on Collector-Current Rise Time.—T. R. Bashkow. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. ED-3, No. 4, pp. 167–172. Abstract, *Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, p. 254.)

621.314.7 : 546.289 **4043**

Application Aspects of the Germanium Diffused-Base Transistor.—D. E. Thomas & G. C. Dacey. (*Trans. Inst. Radio Engrs*, March 1956, Vol. CT-3, No. 1, pp. 22–25. Abstract, *Proc. Inst. Radio Engrs*, July 1956, Vol. 44, No. 7, p. 952.)

621.314.7 : 621.318.57 **4044**

Solution of a Transistor Transient Response Problem.—J. R. Macdonald. (*Trans. Inst. Radio Engrs*, March 1956, Vol. CT-3, No. 1, pp. 54–57. Abstract, *Proc. Inst. Radio Engrs*, July 1956, Vol. 44, No. 7, p. 953.) See also 885 of 1955 (Moll).

621.314.7.001.4 **4045**

Measuring Parameters of Junction Transistors.—R. W. Hendrick, Jr. (See 3950.)

621.314.7.012 : 621.317.755 **4046**

Investigation of Transistor Characteristics by means of a Cathode-Ray Curve Tracer.—Bonch-Bruevich & Soltamov. (See 3951.)

621.314.7 + 621.375.4].012.8 **4047**

Electric-Network Representation of Transistors—a Survey.—R. L. Pritchard. (*Trans. Inst. Radio Engrs*, March 1956, Vol. CT-3, No. 1, pp. 5–21. Abstract, *Proc. Inst. Radio Engrs*, July 1956, Vol. 44, No. 7, p. 952.)

621.383 **4048**

Photoelectric Cells.—J. D. McGee. (*Proc. Instn elect. Engrs*, Part B, Sept. 1957, Vol. 104, No. 17, pp. 467–484.) A review of progress. Topics discussed include the theory of the external and internal photoelectric effects, methods of manufacture and measurement, the characteristics of typical photoelectric cells, and photoconductive and photovoltaic cells.

621.385.029.6 **4049**

Application of the Potential Analogue in Multicavity Klystron Design and Operation.—S. V. Yadavalli. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1286–1287.) Using space-charge-wave theory, relations are developed which allow the output/input voltage ratio of a multicavity klystron with arbitrary parameters to be written down. Expressions for the power gain under broad-band conditions are given.

621.385.029.6 **4050**

Description of Operating Characteristics of the Platinotron—a New Microwave Tube Device.—W. C. Brown. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1209–1222.) The platinotron is structurally similar to a magnetron. The electron beam is re-entrant and originates from a cathode coaxial to the r.f. circuit, but, unlike the magnetron, the r.f. circuit is not re-entrant and its characteristic impedance is matched at both ends to two external connections over the frequency range of interest. In operation the device acts as an efficient, broad-band, saturated amplifier when the signal is passed through it in one direction and as a passive network in the other direction. The platinotron may be used as an oscillator of high frequency stability. Details are given of its operation as an amplifier at frequencies in the region of 1 300 Mc/s ('amplitron' operation).

621.385.029.6 **4051**

Platinotron increases Search Radar Range.—W. C. Brown. (*Electronics*, 1st Aug. 1957, Vol. 30, No. 8, pp. 164–168.) The platinotron is a crossed-field microwave tube whose operating frequency is determined externally. It may be used as a wide-band amplifier or as an oscillator; the tube described gives a peak power of 2 MW at frequencies near 1 300 Mc/s.

621.385.029.6 **4052**

Positive Ion Oscillations in Long Electron Beams.—T. G. Mihran. (*Trans. Inst. Radio Engrs*, July 1956, Vol. ED-3, No. 3, pp. 117–121. Abstract, *Proc. Inst. Radio Engrs*, Nov. 1956, Vol. 44, No. 11, pp. 1641–1642.)

621.385.029.6 **4053**

Space-Charge Waves for a Finite Magnetic Field at the Cathode of a Cylindrical Electron Stream.—R. Liebscher. (*Arch. elekt. Übertragung*, May 1957, Vol. 11, No. 5, pp. 214–221.) The plasma wavelength is calculated under the assumption of a finite magnetic focusing field at the cathode.

621.385.029.6 **4054**

Space-Charge Limitation on the Focus of Electron Beams.—J. W. Schwartz. (*RCA Rev.*, March 1957, Vol. 18, No. 1, pp. 3–11.) The motion of electrons within a homocentric uniform-density beam in the presence of space-charge forces is examined. A universal curve for the smallest spot size at the target is obtained. At high beam currents this differs significantly from available curves for the beam cross-section at the point of zero radial velocity.

621.385.029.6 **4055**
Effect of Space Charge on the Interaction of an Electron Stream and a Travelling Electromagnetic Wave.—V. N. Shevchik & V. S. Stal'makhov. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 230–236.) The conditions necessary for establishing backward-wave oscillation are given. Analytical results are compared with experimental data and formulae of other authors.

621.385.029.6 **4056**
The Cascade Bunching of Electrons Applied to the Analysis of the Interaction of Electron Stream and Travelling Magnetic Wave.—V. N. Shevchik & Yu. D. Zharkov. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 237–243.) Expressions are derived for the active and reactive components of electron power. The effect of the interaction of non-synchronous space harmonics on power is examined and results are used for determining the starting conditions for backward-wave oscillators.

621.385.029.6 **4057**
The Reciprocity of the Coupling in Travelling-Wave Valves.—F. Paschke. (*Arch. elekt. Übertragung*, April 1957, Vol. 11, No. 4, pp. 137–145.) The law of reciprocity is proved which states that to obtain a coupled wave and amplification the field of the undisturbed circuit wave must be present at the beam and the field of the undisturbed space-charge wave must be present at the slow-wave structure. For low-noise operation the amplifier should have a large beam diameter, low beam velocity and a large coupling impedance. For an ideal travelling-wave valve the maximum gain per beam wavelength obtainable is shown to be $37 \cdot 5\ (\omega_{p\infty}/\omega)^{2/3}$ dB, where $\omega_{p\infty}/\omega$ is the ratio of plasma frequency to signal frequency.

621.385.029.6 **4058**
Investigation of Noise Characteristics of Travelling-Wave Valves.—A. S. Tager. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 222–229.) The results of experiments made with valves having a movable electron gun are discussed with reference to theoretical investigations.

621.385.029.6 **4059**
Modified Contrawound Helix Circuits for High-Power Travelling-Wave Tubes.—C. K. Birdsall & T. E. Everhart. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. ED-3, No. 4, pp. 190–204. Abstract, *Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, p. 254.) See also 1825 of 1955 (Chodorow & Chu).

621.385.029.6 : 537.533 **4060**
Break-Up of Hollow Cylindrical Electron Beams.—R. L. Kyhl & H. F. Webster. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. ED-3, No. 4, pp. 172–183. Abstract, *Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, p. 254.) For earlier report, see *J. appl. Phys.*, Nov. 1955, Vol. 26, No. 11, pp. 1386–1387 (Webster).

621.385.029.6 : 537.533 **4061**
Instability of Hollow Beams.—J. R. Pierce. (*Trans. Inst. Radio Engrs*, Oct. 1956, Vol. ED-3, No. 4, pp. 183–189. Abstract, *Proc. Inst. Radio Engrs*, Feb. 1957, Vol. 45, No. 2, p. 254.) See also 4060 above.

621.385.029.6 : 537.54 **4062**
On the Interaction between Microwave Fields and Electrons, with Special Reference to the Strophotron.—B. Agdur. (*Ericsson Tech.*, 1957, Vol. 13, No. 1, pp. 3–108.) "The interaction between a microwave field and electrons is investigated theoretically in a system where the electrons oscillate in an electrostatic field and a superimposed microwave field both of which are nonlinear. The operating characteristics of such a system are deduced from the theory. The theoretical results are applied to the strophotron oscillator and the measurements performed are in satisfactory agreement with the theory. Of special interest is the fact that both theory and experiments show that it is possible to combine high efficiency with good electronic tuning properties of the tube." See also 3398 of 1954 (Alfvén & Romell).

621.385.029.6 : 621.318.2 **4063**
The Design of Periodic Permanent Magnets for Focusing of Electron Beams.—F. Sterzer & W. W. Siekanowicz. (*RCA Rev.*, March 1957, Vol. 18, No. 1, pp. 39–59.) An extension to the theory of Chang (1202 and 2793 of 1955).

621.385.029.6 : 621.372.2 **4064**
The Interpretation of Homogeneous Delay Systems.—A. I. Shtyrov. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 244–251.) The propagation of slow electronic waves in periodic structures of filter type based on internal reflection is compared with propagation in a rectangular comb-type delay structure formed by an anisotropic dielectric.

621.385.029.6 : 621.375 : 621.396.822 **4065**
The Minimum Noise Figure of Unmatched Amplifiers.—H. Pötzl. (*Arch. elekt. Übertragung*, April 1957, Vol. 11, No. 4, pp. 177–181.) The work of Haus & Robinson (3442 of 1955) is generalized to apply to amplifiers, particularly microwave beam amplifiers, under any conditions of matching. The representation of an amplifier by a scattering matrix is discussed.

621.385.029.6 : 621.396.662 **4066**
Tuning of Interdigital Magnetrons by Coaxial Lines.—A. Singh. (*J. Electronics Control*, Aug. 1957, Vol. 3, No. 2, pp. 183–193.) The interdigital magnetron, especially the inverted form with the cathode outside the anode, is shown to be especially suitable for tuning by a coaxial line since it has only one cavity. Tuning ranges of 2 : 1 are calculated and confirmed by cold measurements. Suggested modifications should give wider ranges.

621.385.029.6 : 621.398.822 **4067**
Validity of Travelling-Wave-Tube Noise Theory.—R. C. Knechtli & W. R. Beam. (*RCA Rev.*, March 1957, Vol. 18, No. 1, pp. 24–38.) Experimental results are presented which are substantially in agreement with the first-order theory of noise based on a single space-charge wave. Zero correlation was found between beam-current and electron velocity fluctuations at the potential minimum in front of the cathode.

621.385.029.64 : 621.373.4.018.75 **4068**
Technique of Pulsing Low-Power Reflex Klystrons.—J. I. Davis. (*Trans. Inst. Radio Engrs*, Jan. 1956, Vol. MTT-4, No. 1, pp. 40–47. Abstract, *Proc. Inst. Radio Engrs*, April 1956, Vol. 44, No. 4, p. 581.)

621.385.032.21 **4069**
Modern Thermionic Cathodes.—R. W. Fane. (*Wireless World*, Oct. 1957, Vol. 63, No. 10, pp. 488–490.) A review of the main types and their relative merits. Possible future developments in the microwave field are described; for all ordinary low-current applications the oxide cathode is still preferred.

621.385.032.21 : 537.568 **4070**
Study of a Method for Reducing the Auto-electronic Cathode Bombardment by the Ions of Residual Gases.—M. I. Elinson, V. A. Gor'kov & G. F. Vasil'ev. (*Radiotekhnika i Elektronika*, Feb. 1957, Vol. 2, No. 2, pp. 204–218.)

621.385.032.213.2 **4071**
The Relationship between Cathode Emission, Cathode Resistance and Mutual Conductance in Receiving Valves.—M. F. Holmes. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 251–264.) Techniques available for the measurement of cathode emission and resistance in a normal valve are considered. Reasonable quantitative relations between the parameters are examined and compared with experimental life-test records.

621.385.032.216 **4072**
The Conductivity of Oxide Cathodes: Part 1—Potential Distribution.—G. H. Metson. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 316–322.) For various operating conditions found in common receiving valves, experiments show that in a well-activated cathode the potential gradient is constant across the oxide matrix but may increase towards the outer surface as deactivation occurs.

621.385.032.216 **4073**
The Conductivity of Oxide Cathodes: Part 2—Influence of Ion Movements on Matrix Resistance.—G. H. Metson. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 496–505.) A discussion of the influence of residual gas ions, and oxygen matrix, on the matrix resistance. For Part 1 see 4072 above.

621.385.032.216 **4074**
Lifetime of Oxide Cathodes.—W. Dahlke. (*Telefunken Ztg*, March 1957, Vol. 30, No. 115, pp. 55–61. English summary, p. 75.) The results of investigations on versions of the h.f. pentode Type EF80 are analysed. Five different core-metal alloys

were tested with underheated, overheated, or normally heated filaments and under various load conditions. The corresponding valve characteristics are plotted against hours of operation. The relation of cathode life expectancy to heater voltage is shown for one of the core materials. Above and below the optimum operating temperature cathode poisoning reduces the emission. Results of tests on the u.h.f. triodes Type 2C39A and Type 2C40 are also given.

621.385.1.032.29 **4075**

Growth of Anode-to-Grid Capacitance in Low-Voltage Receiving Valves.—F. H. Reynolds, C. B. Johnson & M. W. Rogers. (*Proc. Instn elect. Engrs*, Part B, Sept. 1957, Vol. 104, No. 17, pp. 487–492.) "The capacitance between the anode and the control grid of a certain type of receiving pentode has been found to increase with life, the rate of growth being dependent on the operating conditions of the valve and on the material and processing schedule of the anode. It is shown that the phenomenon is due to the transfer of impurity carbon from the anode to the mica insulators."

621.385.2 : 537.525.92 **4076**

The Space-Charge-Limited Flow of Charged Particles in Planar, Cylindrical and Spherical Diodes at Relativistic Velocities.—E. W. V. Acton. (*J. Electronics Control*, Aug. 1957, Vol. 3, No. 2, pp. 203–210.) The Langmuir and Child equations are extended to the case of relativistic velocities and the solutions are valid for any value of accelerating voltage.

621.385.3 **4077**

Perturbation Analysis of Stationary Dense Electron Flow and a Space-Charge-Limited Triode.—G. A. Stuart & B. Meltzer. (*J. Electronics Control*, July 1957, Vol. 3, No. 1, pp. 51–62.) The perturbation method is used to deduce the electron flow in planar, cylindrical and spherical triodes from the rectilinear flow in diodes of the same shape. The analysis is restricted to a range of positive grid voltages.

621.385.3 **4078**

On the Amplification Factor of the Triode.—E. B. Moullin. (*Proc. Instn elect. Engrs*, Part C, Sept. 1957, Vol. 104, No. 6, pp. 538–541.) Discussion on 2649 of August.

621.385.3 (09) **4079**

Birth of the Electron-Tube Amplifier.—F. B. Llewellyn. (*Radio & Telev. News*, March 1957, Vol. 57, No. 3, pp. 43–45.) Historical review of the early work of Lee de Forest and his contemporaries.

621.385.3.029.64 **4080**

Microwave Triode Oscillators.—C. L. Andrews. (*Rev. sci. Instrum.*, June 1957, Vol. 28, No. 6, pp. 443–447.) Disk-seal triodes have been scaled down to give oscillators for frequencies of 4–6 kMc/s. The upper frequency limit is imposed by the internal circuit and not by the electronics of the valve.

621.385.5.011.2 **4081**

The Internal Resistance of a Radio-Frequency Pentode.—J. L. H. Jonker & Z. van Gelder. (*Philips Res. Rep.*, April 1957, Vol. 12, No. 2, pp. 141–175.) Detailed analysis of the distribution of current between screen grid and anode taking account of the reflection of electrons by the suppressor grid and by the anode, and the extra space charge due to these electrons. To obtain a high value of internal resistance R_i the reflection coefficient of the suppressor grid must be small, but the effective potential must be kept low. Measurements made on conventional r.f. pentodes and on specially constructed valves are reported. Calculated values of R_i are about 40% above measured values. See also 265 and 3179 of 1951 (Jonker).

621.385.832 **4082**

The Heating of Fluorescent Screens Bombarded by Electrons.—G. D. Archard & P. A. Einstein. (*Brit. J. appl. Phys.*, June 1957, Vol. 8, No. 6, pp. 232–236.) The temperature rise is calculated for various forms of bombardment, and fair agreement is found with experimental results. Application to practical c.r. tubes is considered.

621.385.832 : 535.371.07 **4083**

The Movement of the Second Cross-over Potential of Insulators.—A. B. McFarlane. (*Brit. J. appl. Phys.*, June 1957, Vol. 8, No. 6, pp. 248–252.) By suitable treatment of the luminescent screen of a c.r. tube, e.g. by settling it in a strong silicate solution or by applying a layer of magnesium oxide smoke to the bombarded surface, the second crossover potential can be made to follow closely the applied anode voltage. This allows the application of almost unlimited voltages, with a consequent gain in luminance and performance.

621.385.832 : 621.396.662 **4084**

Problems of Comparative Tuning Indication.—G. Linckelmann. (*Telefunken Ztg*, March 1957, Vol. 30, No. 115, pp. 62–69. English summary, p. 75.) Various methods of comparing two signal voltages by means of 'magic eye'-type indicators are discussed. Details are given of the indicator tube Type EMM 801 which has a single cathode. For an application of this tube, see 1455 of May (Troost).

621.387 : 621.3.032.12 : 546.293 **4085**

Influence of Argon Content on the Characteristics of Glow-Discharge Tubes.—F. A. Benson & E. F. F. Gillespie. (*Proc. Instn elect. Engrs*, Part B, Sept. 1957, Vol. 104, No. 17, pp. 498–506.) A discussion on specially manufactured neon-filled and helium-filled tubes having argon contents from zero to 3·5%. 35 references.

MISCELLANEOUS

061.6 : 621.396 **4086**

The New Radio Research Station, Ditton Park, Slough.—R. L. Smith-Rose. (*Nature, Lond.*, 27th July 1957, Vol. 180, No. 4578, pp. 163–166.) A summary of the program of research and of its part in an international range of activities. See also 3461 of 1955.

389.6 (43) **4087**

50 Years of the A.E.F. [Committee for Units and Symbols].—E. Flegler. (*Elektrotech. Z., Edn A*, 11th April 1957, Vol. 8, No. 8, pp. 273–295.) This issue contains nine papers dealing with the history, achievements and tasks of the Committee.

621.3.03 : 356/359 **4088**

Component Developments.—G. W. A. Dummer. (*Wireless World*, Oct. 1957, Vol. 63, No. 10, pp. 482–485.) Trends in design and testing of electronic components used by the Armed Services.

621.3.049.75 **4089**

Components for Printed Circuits.—L. W. D. Sharp. (*Brit. Commun. Electronics*, April 1957, Vol. 4, No. 4, pp. 202–207.) The design features of the various types of component and the methods of insertion and of fixing to wiring boards are tabulated and discussed. Recent mechanical improvements are described and future trends outlined.

621.3.049.75 **4090**

Recent Advances in Automatic Assembly.—L. H. Gipps & K. M. McKee. (*J. Brit. Instn Radio Engrs*, Sept. 1957, Vol. 17, No. 9, pp. 501–511.) Recent and probable future development of machines for preparing electronic components and inserting them automatically into printed wiring boards are considered. The design of components and the processing of printed wiring boards are discussed in relation to the requirements of automatic assembly.

621.317+681.142] : 061.3 **4091**

I.R.E. Instrumentation Conference and Exhibit.—(*Trans. Inst. Radio Engrs*, June 1956, Vol. PGI-5, pp. 1–224.) Text of 32 papers read at the Conference in Atlanta, Georgia, 28th–30th November 1955, under the headings: recording and data utilization, data handling systems, processing techniques, analogue-to-digital conversion, and transducers. For abstracts of papers, see *Proc. Inst. Radio Engrs*, Sept. 1956, Vol. 44, No. 9, pp. 1210–1213.

621.37/.39(091) **4092**

A History of some Foundations of Modern Radio-Electronic Technology.—J. H. Hammond, Jr, & E. S. Purington. (*Proc. Inst. Radio Engrs*, Sept. 1957, Vol. 45, No. 9, pp. 1191–1208.)

ABSTRACTS AND REFERENCES INDEX

The Index to the Abstracts and References published throughout 1957 is in course of preparation and will be available with the March 1958 issue. As usual, a selected list of the journals scanned for abstracting, with publishers' addresses, will be included.

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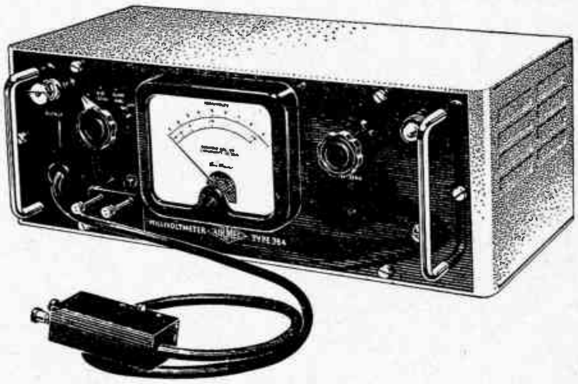

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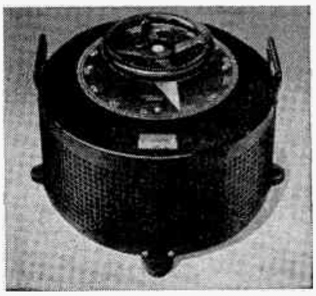

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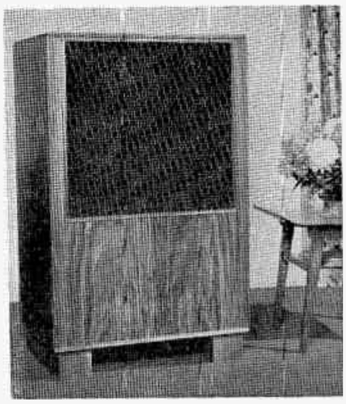

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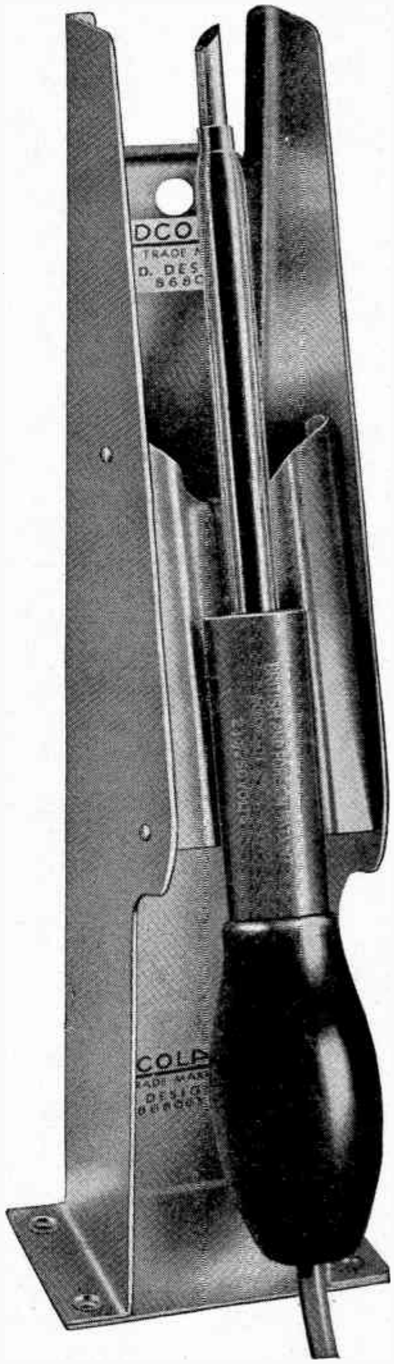

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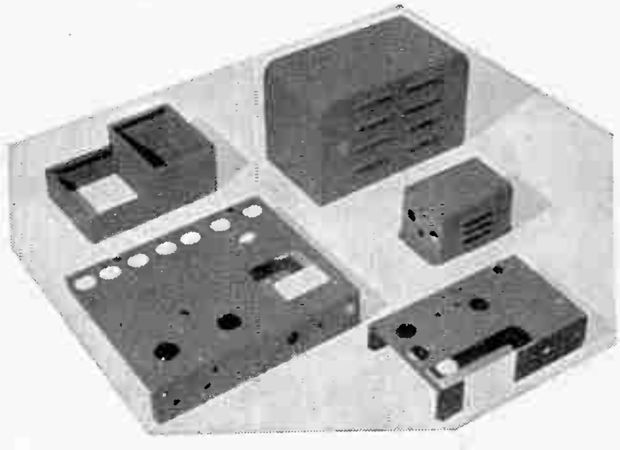

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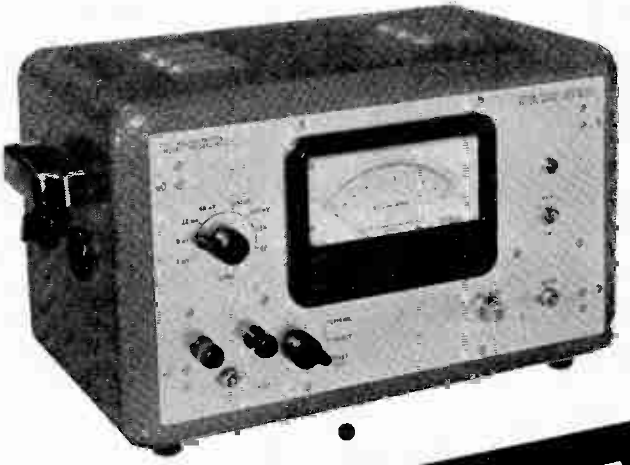

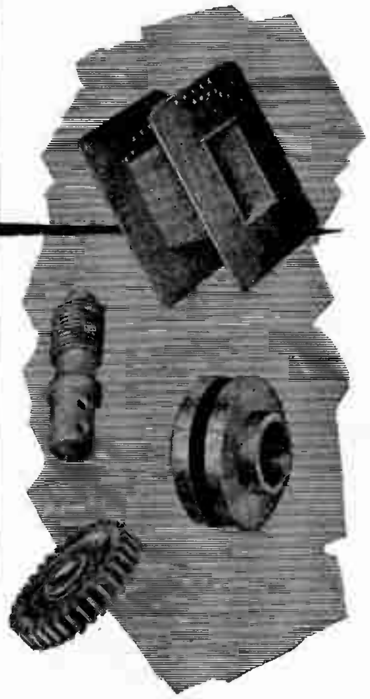


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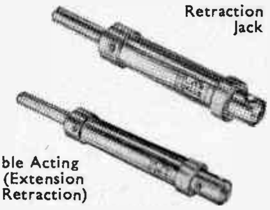

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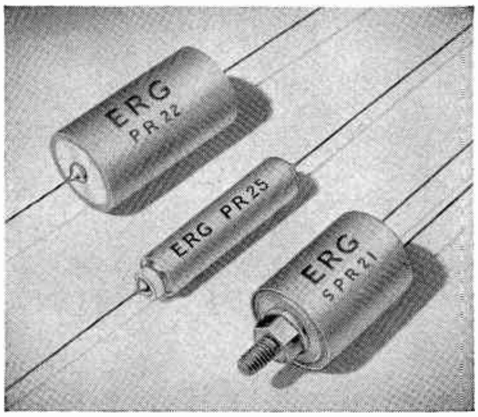

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PR 24		1⅞"	½"	1·0	·65	·32	0·1	350K
PR 25		1⅜"	⅜"	0·5	·32	·16	0·1	100K
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Test	Duration	Spec.	Average % Change
Full DC Load	1,000 hours		·013
Tropical Exp. ...	84 days	RCS 11	·027
Climatic Cycles ...	6 Cycles	RCS 11 Climatic	·01
Tropical Exposure + Light DC Load ...	2,500 hours	RCS 111	·02
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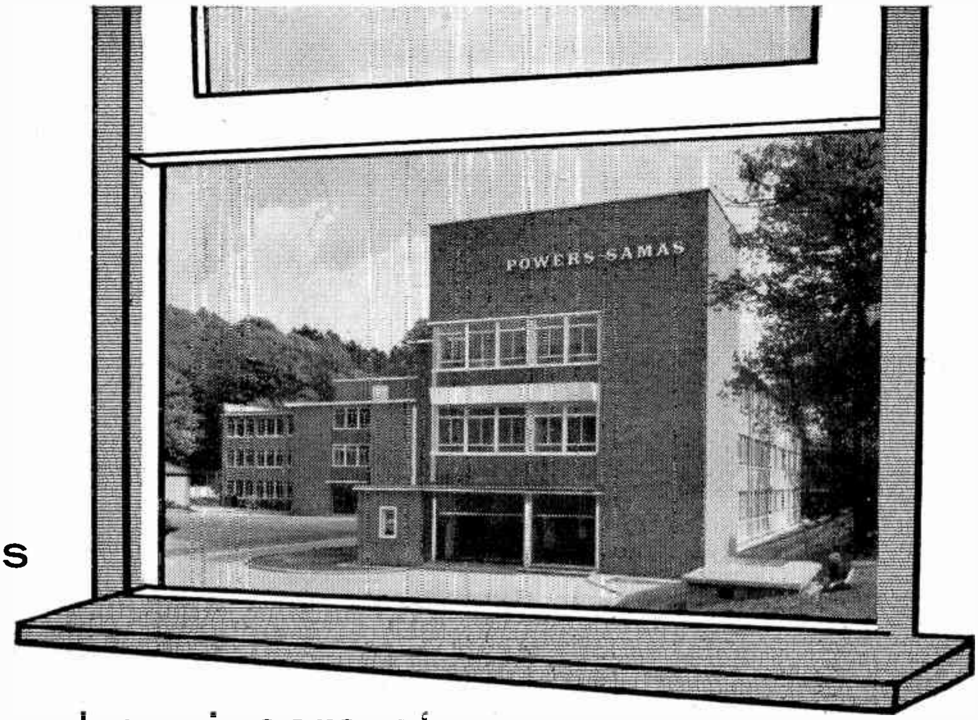

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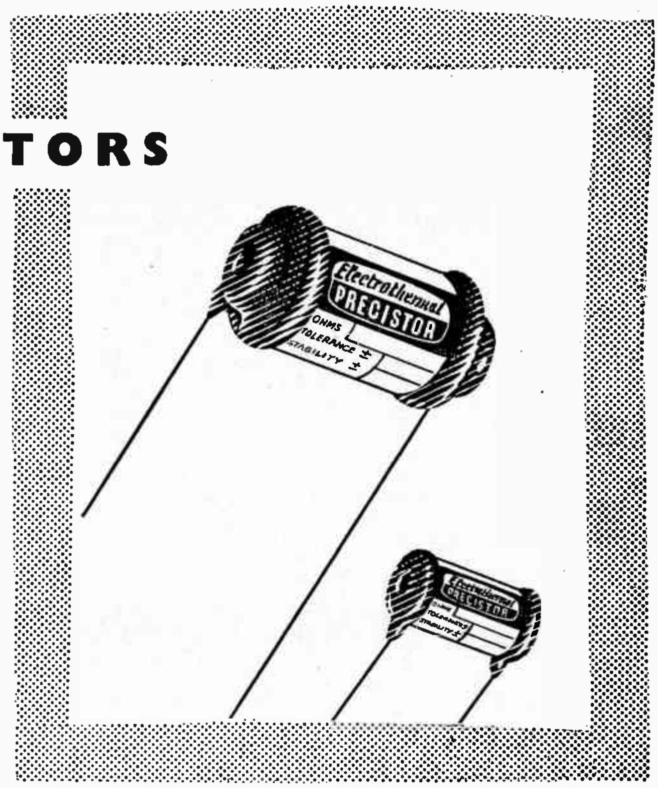

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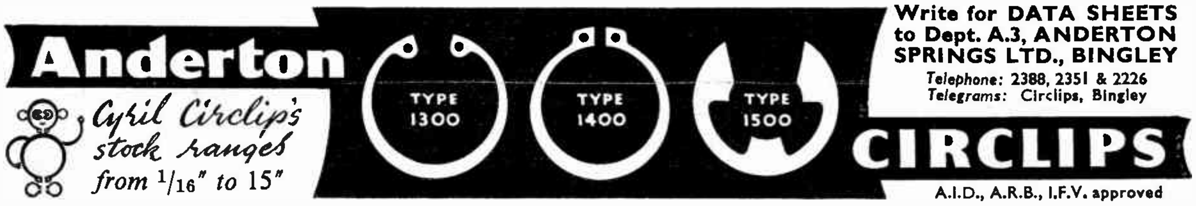

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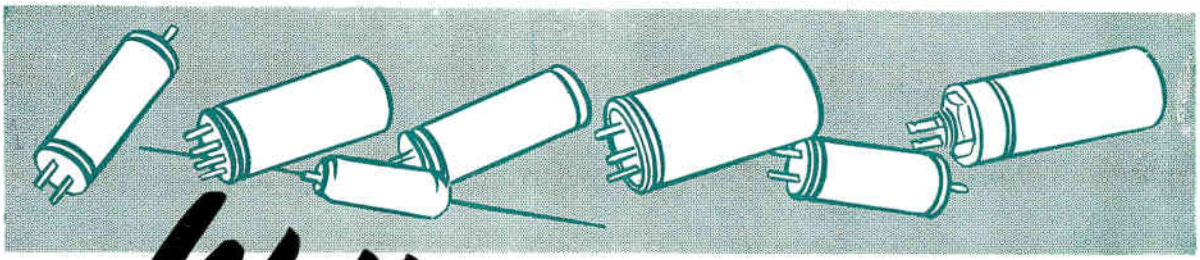

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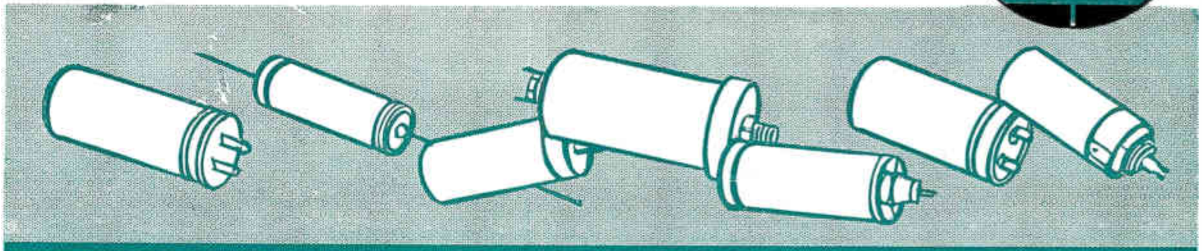

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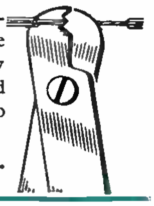
This 3 in 1 tool strips insulation without nicking the wire, cuts wire cleanly and splits plastic extruded twin flex. Adjustable to most wire thicknesses.
3/6 each (subject).



Bib RECORDING TAPE SPLICER

An excellent splicer incorporating many refinements and quickly saving its cost in tape economies, complete with razor cutter. 18/6 each (subject).

MULTICORE SOLDERS LIMITED, MULTICORE WORKS, HEMEL HEMPSTEAD, HERTS. (BOXMOOR 3636)