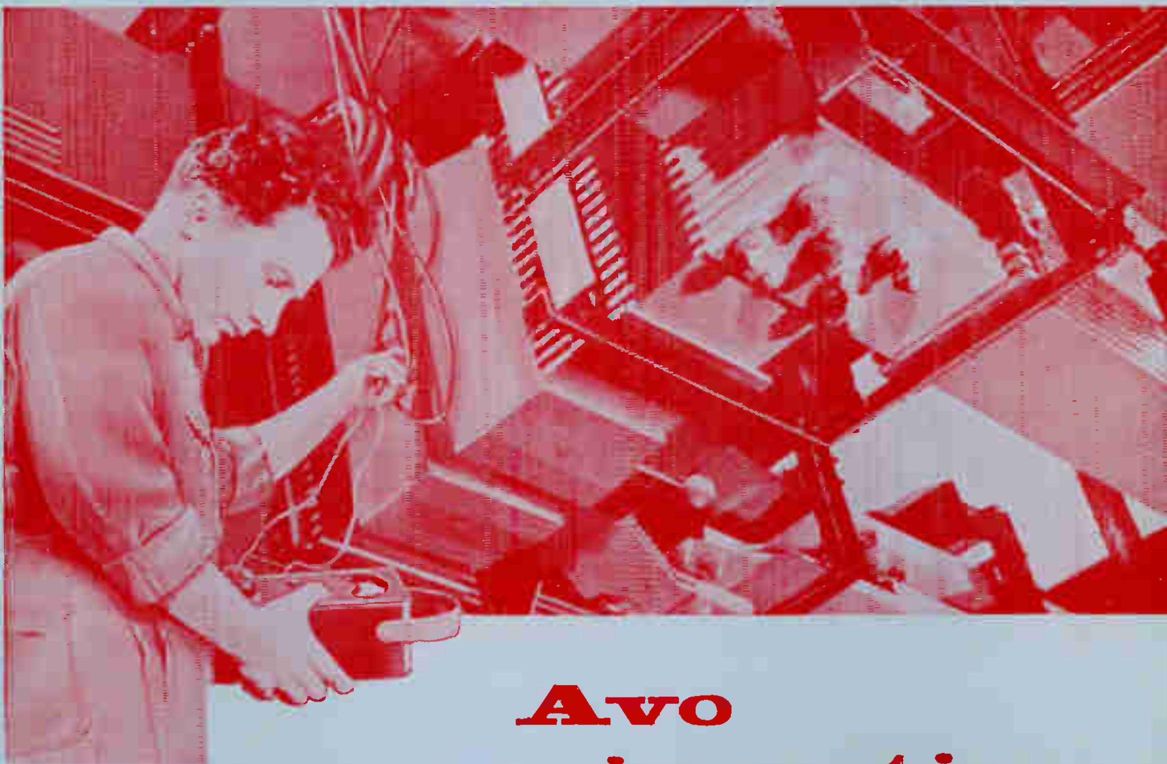
# WIRELESS ENGINEER

THE JOURNAL OF RADIO RESEARCH & PROGRESS

## JUNE 1956

VOL. 33 No. 6 · THREE SHILLINGS AND SIXPENCE

World Radio History



Photograph by courtesy of British Insulated Callender's Cables, Ltd.

# Avo in action ...

The checking of a busbar installation in a large steel works is an interesting example of the important contribution of the world-famous AvoMeter to the maintenance of electrical power plant. AvoMeters will be found wherever electricity is used in industry.

## Model 40 Universal AvoMeter

A self-contained multi-range A.C./D.C. instrument providing 40 ranges of direct readings of current, voltage and resistance on a 5-inch hand calibrated scale fitted with an anti-parallax mirror. Range selection is by two rotary switches, for A.C. and D.C. respectively, and a press button provides additional ranges by halving the current and voltage ranges shown on the switch knobs. The total resistance of the meter is 200,000 ohms.

The instrument is compact and portable, and is protected by an automatic cut-out against damage through the inadvertent application of overload.

Power Factor and reactive kV.A. can be measured in A.C. circuits by means of an external accessory (the Universal AvoMeter Power Factor & Wattage Unit).

Size: 8 × 7¼ × 4½ ins.
Weight: 6¾ lbs.

List Price
£19 : 10s.

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*Sole Proprietors and Manufacturers:—*

**THE AUTOMATIC COIL WINDER & ELECTRICAL EQUIPMENT CO., LTD.**

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A40/3




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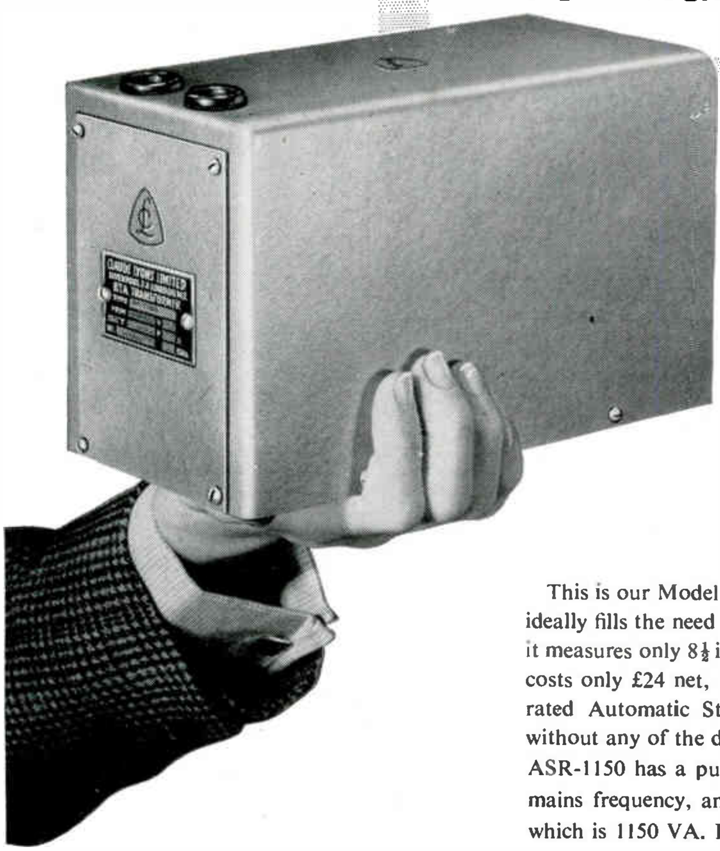
# A NEW-PRINCIPLE A-C AUTOMATIC VOLTAGE STABILISER



This is our Model ASR-1150 Automatic Voltage Step Regulator. It ideally fills the need for a cheap, small and light Stabiliser. Although it measures only 8½ in. × 4½ in. × 5 in., weighs as little as 11 lb., and costs only £24 net, it has a performance fully equal to any similarly rated Automatic Stabiliser of the resonated, saturated core type, without any of the disadvantages.

ASR-1150 has a pure output waveform, is unaffected by changes in mains frequency, and works equally well from no-load to full load, which is 1150 VA. It has a stabilised output at 230V unless otherwise ordered.

Many other Automatic Voltage Stabilisers are now manufactured by us, and all are available for immediate delivery. In some cases the constancy of output is as high as 0.15%. Models are available from 200 VA to 30 kVA, single phase. 3-Phase Stabilisers are also available. Prices are *extremely* competitive.

**We can supply from stock all types of American tubes, condensers, valves, potentiometers, etc.**

*MEMO: If you are interested in infinitely-variable Transformers, do not forget the almost indispensable "VARIAC" (Reg'd. Trademark). Models are available from 170VA to 21kVA. Our Catalogue V-549 (3rd Edition) tells the whole story and will gladly be mailed free and post free, on request.*

## The *NEW "ASR-1150"* costs only *£24* net

*Complete information is obtainable from:*

**CLAUDE LYONS LTD.,** STABILISER DIVISION,

HEAD OFFICES & WORKS: 76 OLDHALL STREET, LIVERPOOL 3, LANCS.
SOUTHERN FACTORY: VALLEY WORKS, WARE ROAD, HODDESDON, HERTS.
(A10 main London/Cambridge Road, at Junction of A602)

# for radio ceramics

**STEATITE & PORCELAIN PRODUCTS LTD.**

Stourport-on-Severn, Worcestershire. Telephone : Stourport 111. Telegrams : Steatain, Stourport

SP88

# 4 J 50. MAGNETRON

JAN APPROVED

BRITISH SERVICES
TYPE APPROVED

*Full technical data of this Magnetron and others in the range available on request*


## 'ENGLISH ELECTRIC'

**ENGLISH ELECTRIC VALVE CO. LTD.**

*Waterhouse Lane, Chelmsford*
*Telephone : Chelmsford 3491*

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# MICROSECOND CHRONOMETER


*This equipment is designed to measure small intervals of time to a high order of accuracy and two ranges are provided:*

*(1) 1 μsec. to 1 sec. in steps of 1 μsec.*

*(2) 10 μsec. to 10 sec. in steps of 10 μsec.*

*Accuracy of each range is better than ± 0.005% ± the step interval.*

*Full details on this and other 'Cintel' Chronometers are available on request.*

**CINEMA TELEVISION LTD**

A COMPANY WITHIN THE RANK ORGANISATION LIMITED

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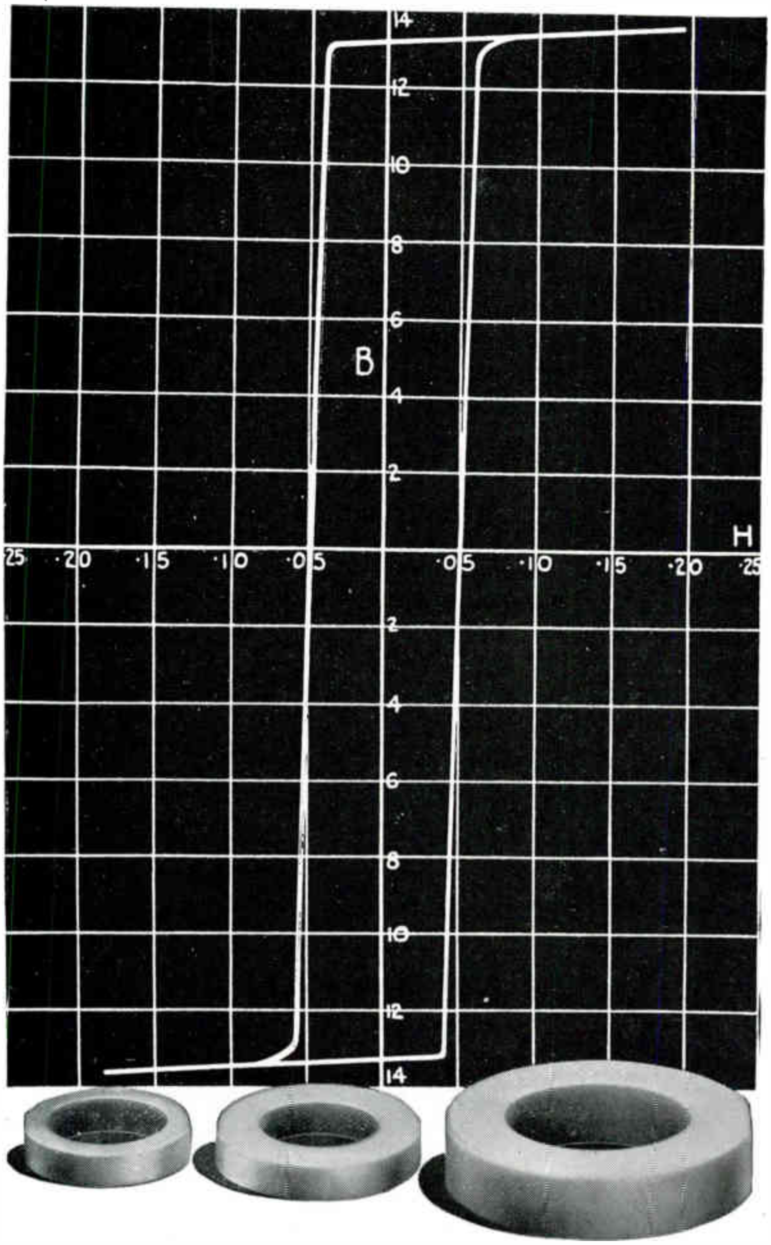



# PERMALLOY 'F'

## the magnetic material with optimum rectangularity

*Magnetic saturation at low field strength. Remanence almost equal to saturation.*

Permalloy 'F' is particularly suitable for MAGNETIC AMPLIFIERS—SATURABLE REACTORS — MEMORY STORAGE DEVICES and other similar applications.

It is supplied in the form of toroidal cores, fully heat-treated and protected by nylon boxes ready for winding.

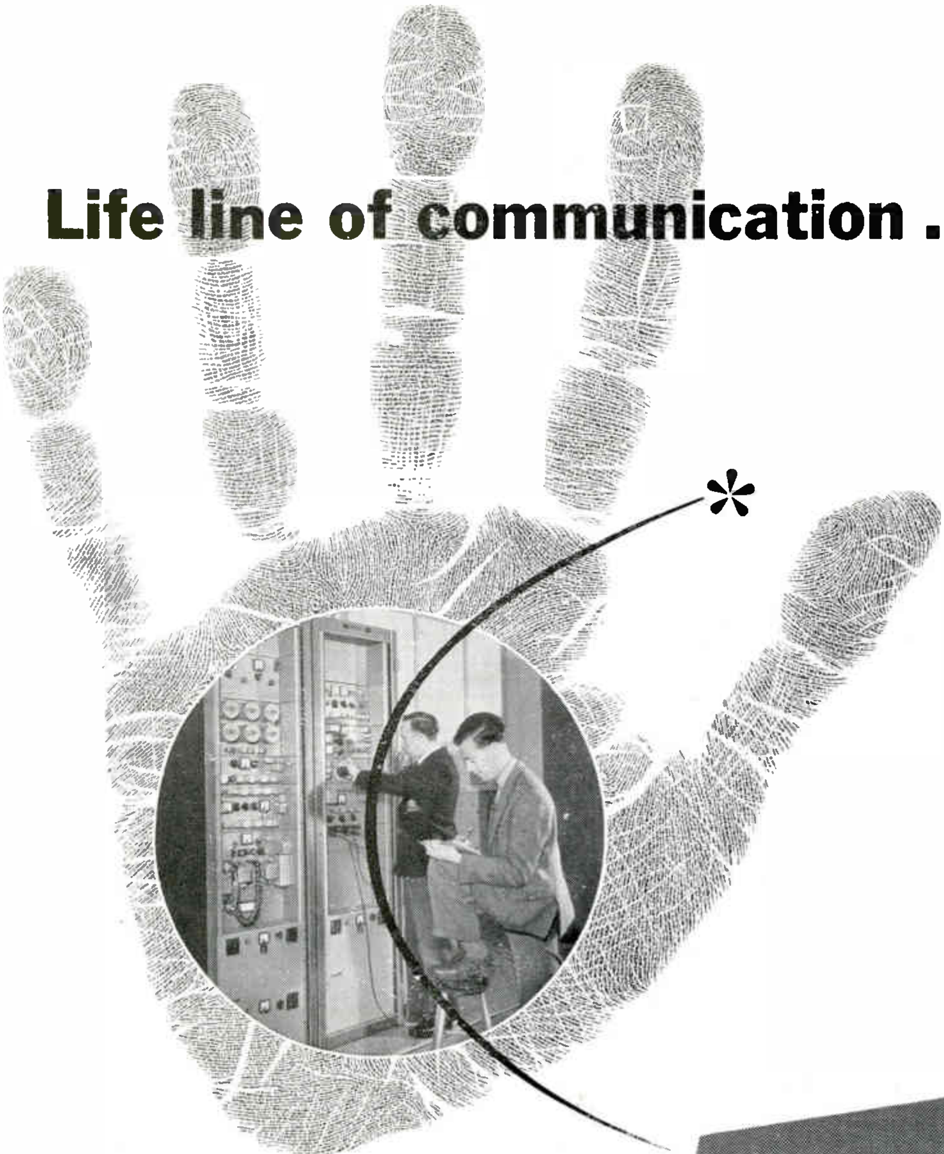
## Standard magnetic materials

## Standard Telephones and Cables Limited

*Registered Office: Connaught House, Aldwych, London, W.C.2*

**TELEPHONE LINE DIVISION:** NORTH WOOLWICH · LONDON · E.16

Life line of communication . . .



World wide radio-communication began with Marconi's Transatlantic messages in 1901. Since then Marconi research and development have led to every major advance in technique. Marconi equipment today, operating at all frequencies, covers a very wide field of both long and short range radio-telegraph and radio-telephone requirements. Marconi VHF multi-channel equipment can provide for as many as 48 telephone channels and is largely superseding land-line or cable routes on grounds of efficiency, economy and, where terrain is difficult, ease of installation and maintenance.

COMPLETE RADIO/TELEPHONE AND RADIO/TELEGRAPH SYSTEMS AND EQUIPMENT

# MARCONI

**Complete Communication Systems**

***Surveyed, Planned, Installed, Maintained***

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX

LG 1



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# DC 10 PRESSURE UNIT

SPECIFICATION

| | |
|---|---|
| Power Handling Capacity | 10 watts peak |
| Voice Coil Impedance | 15 ohms |
| Frequency Response | 120–9000 c.p.s. |
| Flux Density | 12,000 gauss |
| Pole Piece | 1·5″ diameter |

***Price £6 10s. 0d.***

DIMENSIONS

| | DC 10 (without line trs.) | DC 12 (with line trs.) |
|---|---|---|
| Diameter | $4\frac{1}{8}$″ | $4\frac{1}{8}$″ |
| Length | $4\frac{1}{4}$″ | $6\frac{5}{8}$″ |
| Weight | $4\frac{3}{4}$lb. | $5\frac{1}{2}$lb. |

Specially designed and developed to meet the need of the P.A. Engineer requiring a compact, efficient unit combining good tone with average handling capacity, at a price that will make the "small" installation a profitable proposition.

***High Sensitivity*** Heavy cross-sectioned cup with latest anisotropic alloy CP magnet.

***Phase Equalizing Throat*** One-piece zinc based alloy die-casting.

***Self-Centring Diaphragm Assembly*** Can be changed in the field without special tools or soldering iron in $1\frac{1}{2}$ mins.

***Spring Loaded Terminals*** Ensure quick and positive line termination.

***Weatherproof*** Totally enclosed, ensuring protection when in exposed position, watertight gland cable entry.

DC 12 PRESSURE UNIT (WITH TRANSFORMER)
As DC 10 but fitted with totally enclosed 100v line transformer tapped 2·5, 5, 8 and 12 watts.
**PRICE £7 10s. 0d.**

*Manufactured in Gt. Britain by*

**Rola Celestion Ltd.**

FERRY WORKS THAMES DITTON, SURREY

Telephone: EMBerbrook 3402

# *Now Available!*

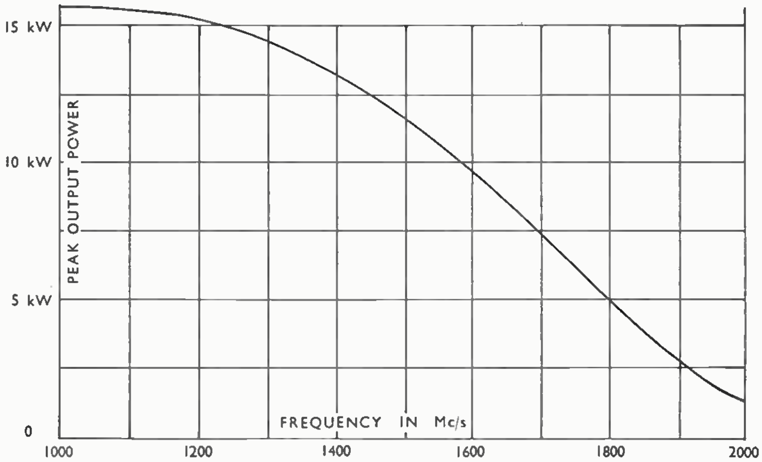
## FERRANTI CERAMIC VALVES

TRIODE TYPE UL10
Less than 2½" x 1" max. dia.

### TRIODE TYPE UL10

RF Output Power under PULSE Conditions

Pulse $V_a$ .......... 4 kV
Pulse Duration .......... 2½ μsec.
P.R.F. .......... 200 p.p.s.




Also suitable for use as C.W. Oscillator or Amplifier giving outputs up to 15 Watts at frequencies up to 1000 Mc/s.

All Ferranti Ceramic Valves have the following outstanding advantages

- LONG LIFE
- REDUCED DIMENSIONS
- HIGH PEAK EMISSION
- HIGH MECHANICAL STRENGTH
- HIGH PERMISSIBLE TEMPERATURE OF OPERATION

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# 5 good reasons for using

## BICC POLYPOLE CABLE COUPLERS!

*Designed for the outdoor connection of Specialized Remote Control Units, Centimetre Radio Links, Ground Radar, Television Camera and Industrial Electronic Equipment.*

- Moulding techniques ensure a tough, permanent, moisture-resistant assembly which virtually eliminates the possibility of conductor breakages at the coupler.
- Screwed lock rings provide forced engagement and withdrawal. The overall metal housing is replaceable if damaged.
- The cable itself is designed with a symmetrical cross section to provide the greatest reliability during handling.
- The conductors are embedded in the moulding in the same geometric formation as in the cable so that each contributes to the strength of the connection.
- Both panel mounting and cable couplers can be supplied with insulated tails and cable lengths respectively cut to meet individual requirements.

*Full details of our standard range of Polypole Couplers and Cables are available on request.*

---

*BICC are always glad to advise on the use of Polypole Couplers and Cable to meet customers' special requirements.*

BI Callender's

**BRITISH INSULATED CALLENDER'S CABLES LIMITED**

21 BLOOMSBURY STREET, LONDON, W.C.1



A*

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Consistency of Performance

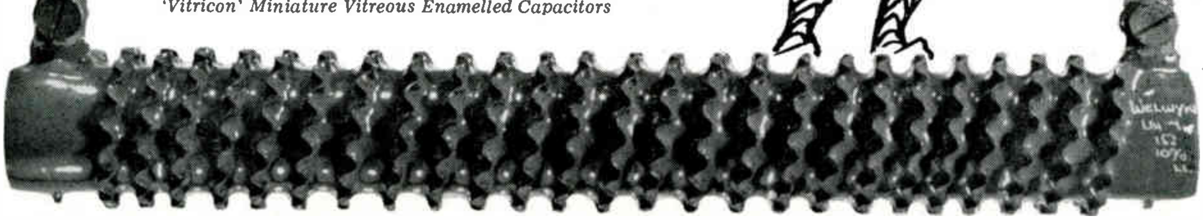
# OVERLOADED BUT UNDISMAYED

Before they leave the factory, batch samples of Welwyn heavy duty resistors are put through their paces in no uncertain manner. Nine times the normal load is passed through. But even this abuse does not daunt the Welwyn heavy duty resistor. It is so designed to involve the maximum, practical weight of resistance element. This means a very high thermal capacity which in turn permits absorption of considerable overcharge surges. The winding tape is protected from the possibility of shorted turns or hot spots by a vitreous enamel coating. Other important features include: a very high intermittent rating, availability in adjustable form and in resistance values as low as 0.1Ω.

MANUFACTURERS OF WELWYN ELECTRICAL COMPONENTS

WELWYN PRODUCTS INCLUDE:

*Toroidally Wound Power Potentiometers*
*Panclimatic High Stability Carbon Resistors*
*Vitreous Enamelled Wirewound Resistors*
*Carbon Composition and Wirewound Potentiometers*
*Insulated High Stability Carbon Resistors*
*High Voltage Composition Resistors*
*'Welmet' Metal Film Resistors*
*'Vitricon' Miniature Vitreous Enamelled Capacitors*



**WELWYN ELECTRICAL LABORATORIES LIMITED · BEDLINGTON · NORTHUMBERLAND**

*On Admiralty, Ministry of Supply (A.I.D. Approved), and Post Office Lists*



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# -*hp*- Announces 2 all new OSCILLOSCOPES

## -*hp*- 130A Low Frequency Oscilloscope

High sensitivity, dc to 300 kc. Sweeps 1 μsec/cm to 15 sec/cm.

## -*hp*- 150A High Frequency Oscilloscope

Dc to 10 Mc. Plug-in preamplifiers. Sweeps 0·02 μsec/cm to 15 sec/cm.

As a result of a totally new design philosophy, -*hp*- 130A and 150A Oscilloscopes set revolutionary standards for oscilloscope usefulness, convenience and rugged dependability. The instruments' wide versatility is indicated in the specifications at left. Their greater convenience and reliability is inherent in such unique features as: Universal automatic triggering system wherein one preset adjustment provides optimum triggering for almost all conditions. Unitized circuits, easily isolated for testing. Etched circuits, mounted on translucent plastic for "see-through" serviceability. Complete accessibility of all circuits and tubes. Highest quality components. Ultra-conservative design, with circuits operating well below rating. Concentric, colour-coded controls, grouped by function and simplified. Direct sweep time selection—no mental gymnastics. A new low capacitance clip-on probe (for -*hp*- 150A) has 10 megohm impedance.

**Get complete data on the most important oscilloscope improvements in history! Call your -*hp*- representative now, or write direct!**

### BRIEF SPECIFICATIONS

#### -*hp*- 130A

**Sweep Range:** 1 μsec/cm to 15 sec/cm.

**Calibration:** 21 sweeps: 1-2-5-10 sequence, 1 μsec/cm to 5 sec/cm. 5% accuracy.

**Triggering:** Internal, line voltage or external 2 v or more. Pos. or neg. slope, + 30 to − 30 v trigger range.

**Preset Trigger:** Optimum setting for automatic stable triggering.

**Input Amplifiers:** (Similar Vert. and Horiz. Amps.) Sensitivity 1 mv/cm to 50 v/cm; 14 ranges, continuous vernier. Pass band dc to 300 kc.

**Amplitude Calibration:** 1 kc square wave. 5% accuracy.

**Price:** $450.00.

#### -*hp*- 150A

**Sweep Range:** 0·02 μsec/cm to 15 sec/cm.

**Calibration:** 24 sweeps: 1-2-5-10 sequence, 0·1 μsec/cm to 5 sec/cm. 3% accuracy.

**Triggering:** Internal, line voltage or external 0·5 v or more. Pos. or neg. slope, + 30 to − 30 v trigger range.

**Preset Trigger:** Same as -*hp*- 130A.

**Horizontal Amplifier:** Magnification 5, 10, 50, 100 times. Vernier selects any 10 cm part of sweep. Pass band dc to over 500 kc. Sensitivity 200 mv/cm to 25 v/cm.

**Vertical Amplifier:** Pass band dc to 10 Mc. Optimum transient response and rise time less than 0·035 μsec. Signal delay of 0·25 μsec permits leading edge of triggering signal to be viewed.

**Amplitude Calibration:** 18 calib. voltages, 2-5-10 sequence, 0·2 mv to 100 v peak-to-peak. Accuracy 3%. Approx. 1 kc square wave, rise and decay approx. 1·0 μsec.

**Prices:** -*hp*- 150A High Frequency Oscilloscope, $1,000.00.
-*hp*- 151A High Gain Amplifier, $100.00.
-*hp*- 152A Dual Channel Amplifier, $200.00.

*Data subject to change without notice.*
*Prices f.o.b. factory.*


**HEWLETT-PACKARD COMPANY**

*Represented by*

**LITHGOW ELECTRONICS LTD.**

1 GRANGE COURT · SUDBURY HILL · HARROW · MIDDLESEX

Telephone: Byron 8783


**Now, more than ever, -*hp*- means "Complete Coverage"**



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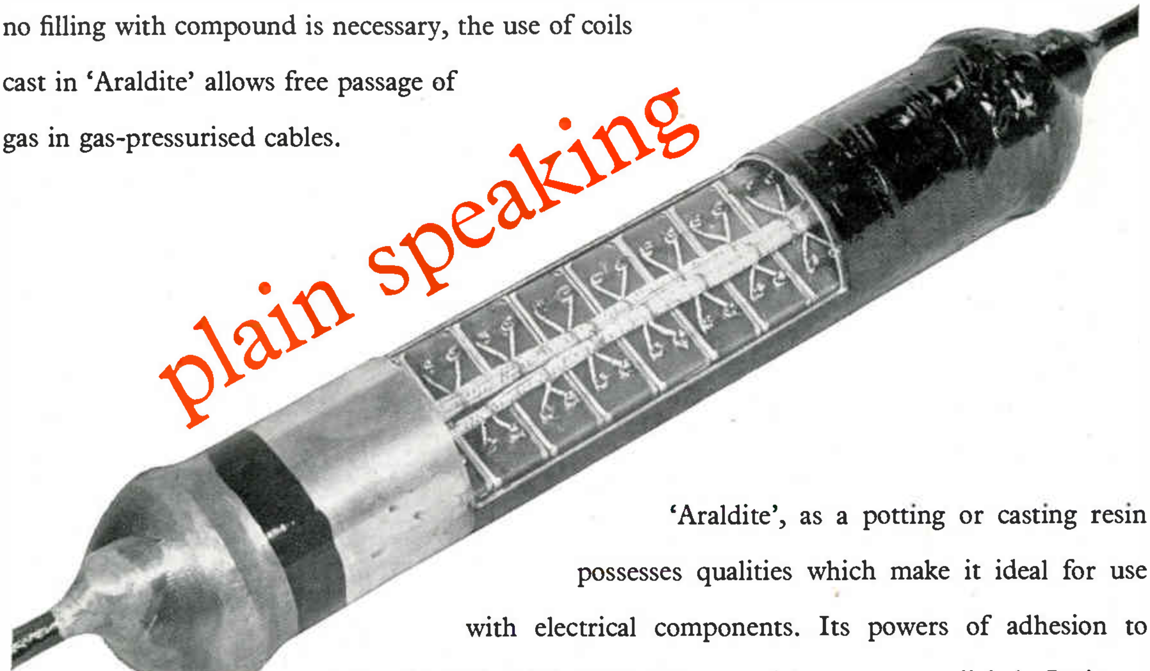
These Mullard Loading Coils represent the latest technique in splice loading of voice frequency cables, whereby the exact number of coils may be installed to meet current requirements. The coils are cast in 'Araldite' epoxy resin which gives complete protection against climatic conditions and permits the use of shapes which will occupy the minimum of space in the joint. As no filling with compound is necessary, the use of coils cast in 'Araldite' allows free passage of gas in gas-pressurised cables.




'Araldite', as a potting or casting resin possesses qualities which make it ideal for use with electrical components. Its powers of adhesion to metals and solid insulating materials are unparalleled. It is an excellent insulator, tough, flexible, highly resistant to 'tracking' and has a low power factor. It does not cause corrosion, provides complete protection against tropical conditions and complies with service requirements relating to sealing of components.

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

They are used

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

*Please write now for full descriptive literature on Araldite Epoxy Resins.*

# 'Araldite' epoxy resins

*'Araldite' is a registered trade name.*

**Aero Research Limited** *A Ciba Company. Duxford, Cambridge. Telephone: Sawston 187*

*AP.264-183A*



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## *for precise control of superior electronic equipment*

## *— moulded track potentiometers by* **Plessey**

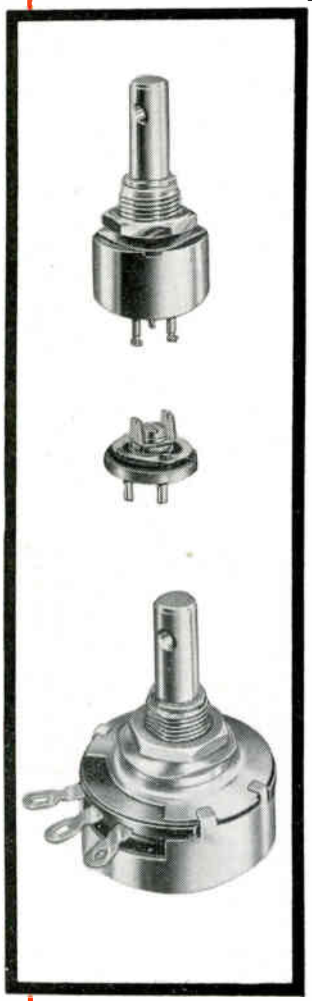
**COMPACT**

The physical confines and electrical parameters of modern electronic equipment makes unprecedented demands on the component manufacturer. His product must almost invariably be smaller than its predecessor and more efficient and durable. These potentiometers provide an outstanding example of what can be achieved to meet the present requirement.

**ACCURATE**

Moulded track potentiometers by Plessey possess a high standard of stability within a wide range of operational temperatures and can be stored for extended periods without deterioration. They can be manufactured to conform, within strictly specified limits, to a designed pattern of values at various positions on the track.

**DURABLE**



The outstanding reliability of these potentiometers is a tribute to the Plessey Research and Development engineers whose efforts to meet the stringent Services requirements and the critical demands of the Commercial market have resulted in products of superior design and function.

### Miniature Type M H 2

A high quality potentiometer for commercial laboratory and Services application. Services Specification RCS122. The standard version is fitted with spindle and panel humidity seals.

**GENERAL SPECIFICATION**

| | |
|---|---|
| Rating: ambient 70°C | ¼ watt |
| Temperature Cat. | 40/70°C |
| Humidity Class | H2 |
| Minimum Resistance | 50 ohms max. |
| Overall Diameter | 23/32 in. |
| Overall depth of control from mounting face, including tags | ⅝ in. |

### Sub Miniature Type G

Type Approved to Certificate No. 974 Issue 1, Ref. TA1373, this pre-set, open-type control is of particular interest to industrial communication and Service equipment manufacturers.

**GENERAL SPECIFICATION**

| | |
|---|---|
| Range Linear ±20% | 1,000 ohms to 2 megohms |
| Rating: ambient 70°C | ¼ watt total track rating |
| Minimum Resistance | 50 ohms max. |

### Spindle and Panel Sealed Type E H 2

For military and para-military applications, this control is particularly resistant to conditions of extreme humidity.
Type Approved to Certificate No. 906, Issue 2, Ref. TA1230.

**GENERAL SPECIFICATON**

| | |
|---|---|
| Rating: ambient 100°C | 1 watt |
| Temperature Cat. | 40/100°C |
| Voltage Limitation | 500V |
| Humidity Class | H2 |
| Minimum Resistance | 50 ohms max. |
| Overall Diameter | 1-5/32 in. |
| Overall depth of control from mounting face | 21/32 in. |

THE PLESSEY COMPANY LIMITED · KEMBREY STREET · SWINDON · WILTS

PS1



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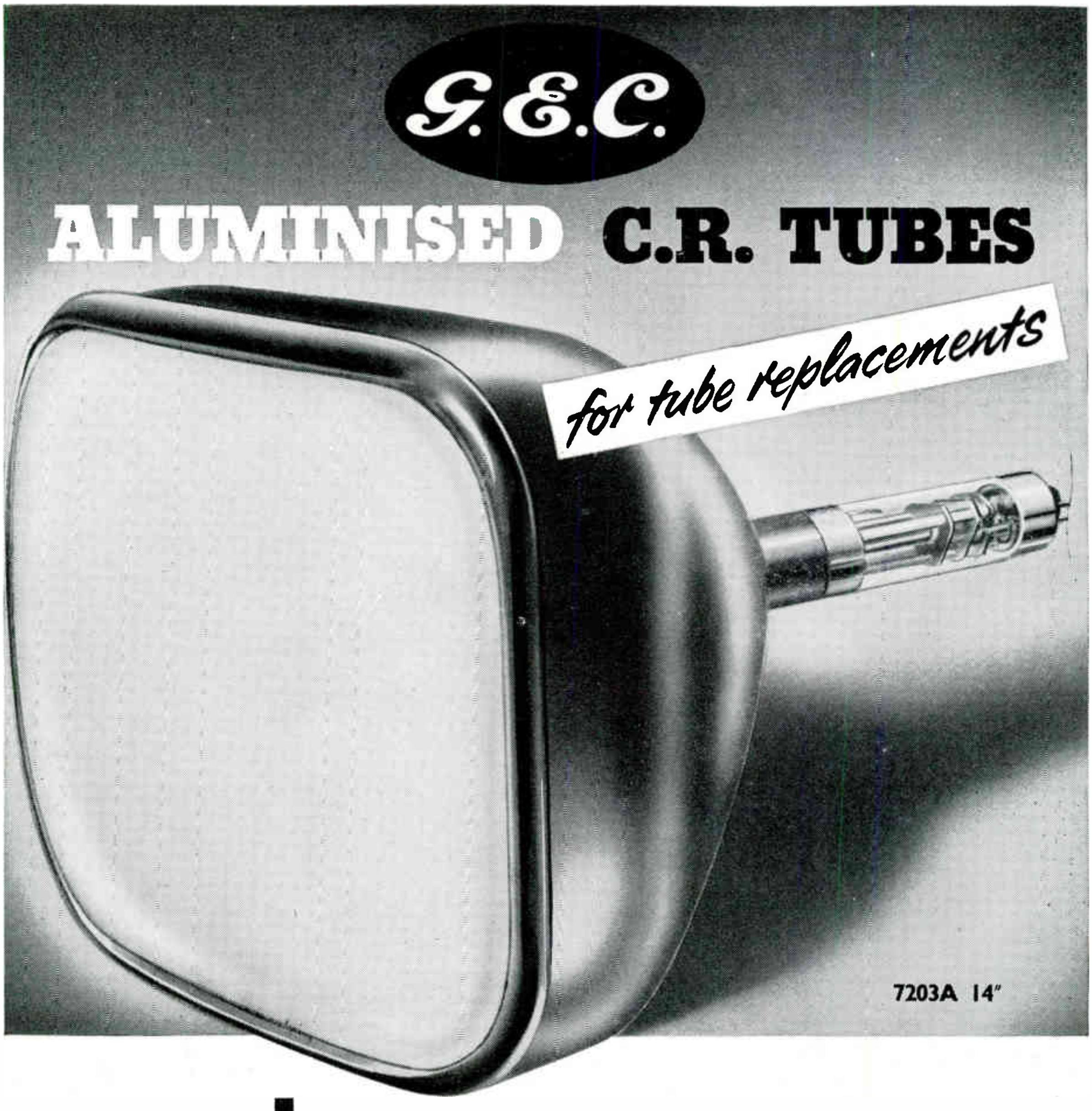


The G.E.C. 14 in. Cathode Ray Tube type 7203A has the following attractive features:—

1) Improved tube life and reliability.

2) A narrow beam angle *triode* gun giving:—

(a) Uniform focus over the entire screen area.

(b) Small spot size.

(c) Freedom from astigmatism.

3) A high reflectance aluminium backing to the fluorescent screen giving:—

(a) 70% increase in picture brightness.

(b) High contrast daylight viewing.

(c) Complete elimination of ion burn from both positive and negative ions.

*Price* **£14 . 15 . 0**
*P. Tax* **£6 . 18 . 1**

THE GENERAL ELECTRIC CO. LTD., MAGNET HOUSE, KINGSWAY, LONDON, W.C.2



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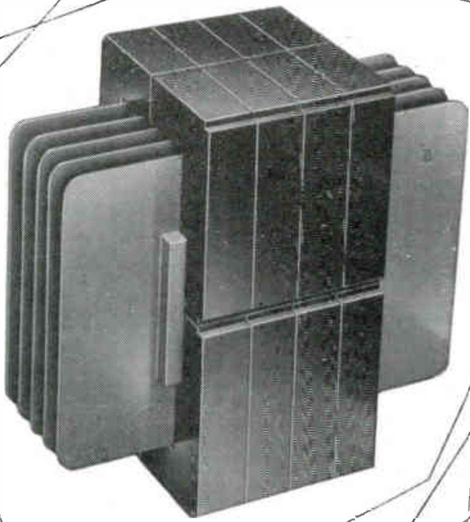

# H.F. POWER TRANSFORMERS

H.F. power transformers of outstanding efficiency are the latest additions to the Mullard range of high quality components designed around Ferroxcube magnetic cores.

Utilising the unique characteristics of Ferroxcube to the full, Mullard H.F. transformers are smaller, lighter, and less costly than transformers using alternative core materials. These advantages are particularly marked in transformers required to handle powers of up to 2kW, between the frequency range 2kc/s to 2Mc/s.

Mullard transformers are already finding wide use in applications as diverse as ultrasonic H.F. power generators and aircraft power packs operating from an aircraft's normal A.C. supply. In the latter application, the low leakage field of Ferroxcube can eliminate the need for external screening, thereby reducing the size and weight of the transformer even further.

As with all Mullard high quality components, these H.F. power transformers are designed and built to engineers' individual specifications. Write now for details of the complete range of components available under this service.

**RATING . . . . . . . . . . . . UP TO 2 kW**

**FREQUENCY RANGE . . . . 2 Kc/s to 2 Mc/s**

**Mullard**

**'Ticonal' permanent magnets**
**Magnadur ceramic magnets**
**Ferroxcube magnetic cores**

MULLARD LTD · COMPONENTS DIVISION · CENTURY HOUSE · SHAFTESBURY AVENUE · WC2

MCIA



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# WIRELESS ENGINEER

**The Journal of Radio Research and Progress**

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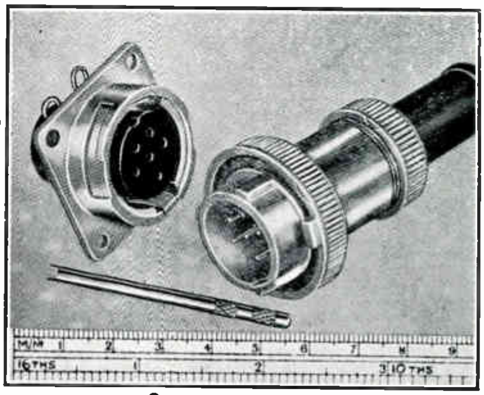
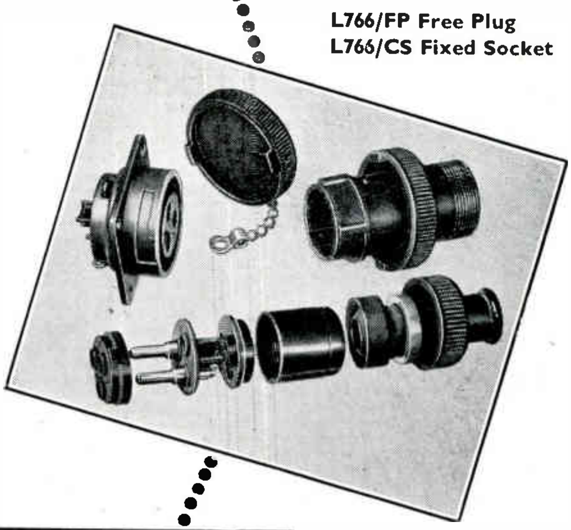
# 'BELLING-LEE'

# Multipole Screened Plugs and Sockets




L766/FP Free Plug
L766/CS Fixed Socket

The "Belling-Lee" range of screened plugs and sockets is designed for use with braided and insulated multicore cables. The gold-plated plug and socket assemblies are interchangeable in their housings, the latter being the same as those used for our L.764 series of coaxial plugs and sockets except that the insulant is nylon filled phenolic material. The protective cover is also common to all types.



L1327/FP Free Plug
L1327/CS Fixed Socket

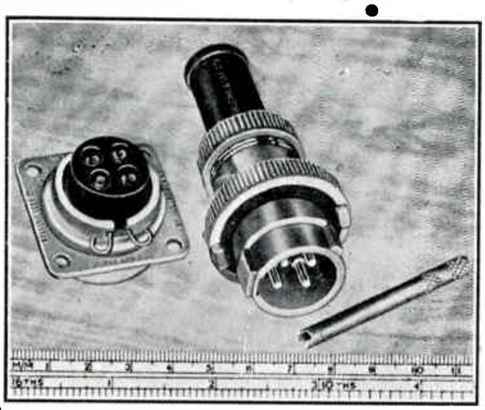
The exploded view shows the various piece parts of the free member

| | | | |
|---|---|---|---|
| 2-pole | Free plug *L.1327/FP | Fixed socket | L.1327/CS |
| 3-pole | *L.1326/FP | | L.1326/CS |
| 4-pole | L.765/FP | | L.765/CS |
| 6-pole | L.766/FP | | L.766/CS |
| 12-pole | L.767/FP | | L.767/CS |

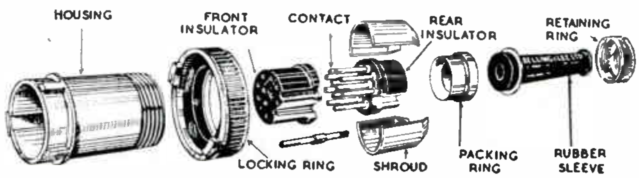
* Waterproof with black anodised finish, to Lloyd's specification of requirements for shipping.
U.K. Pat. 715574.

Protective cover L.764/CA/ anodised or polished L.764/C/Polished.

| Contact Assembly | Max. Cable dia. |
|---|---|
| 2-pole 15 amp. | 0.38 in. |
| 3-pole 15 amp. | 0.38 in. |
| 4-pole 19 amp. | 0.45 in. |
| 6-pole 5 amp. | 0.32 in. |
| 12-pole 5 amp. | 0.41 in. |




L765/FP Free Plug
L765/CS Fixed Socket

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# WIRELESS ENGINEER

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## Physical Society's Exhibition

THIS 40th exhibition of scientific instruments and apparatus, which was held from 14th to 17th May, has so grown that, this year, it occupied both the Old and the New Horticultural Halls. In spite of this, it was at times uncomfortably crowded but it was, nevertheless, a great improvement on last year, when only the New Hall was used. We remarked last year that the break with the tradition of holding it at Imperial College had made the exhibition lose much of its distinctive character. Oddly enough, and most pleasantly, it seemed this year to regain much of its old character and we no longer felt strangers in a strange exhibition.

One of the biggest and most crowded of the exhibits was the one arranged by the Colour Group of the Physical Society to demonstrate some of the principles of colour television. It included 20 main items starting with trichromatic vision, synthesis of colours by three-colour additive mixture and the specification of colour. The additive mixture of phosphor colours and of colour images were demonstrated by an analogy drawn between the eye and colour television. Colour analysis and synthesis, gamma correction and dichroic mirrors were explained, while a projection system, the R.C.A. tricolour tube, and the Lawrence tube were demonstrated. Field, line and dot-sequential scanning systems were also demonstrated as well as the separation of chrominance and luminance, colour discrimination in small fields and chrominance coding. The final exhibits covered compatibility, tolerance to colour balance and alternative luminance-chrominance transmission systems. It should, perhaps, be made clear that the demonstrations did not take the form of true pictures, but of artificial patterns.

Many of the main items included several sub-items and the exhibit as a whole was one of those outstanding ones which deserved a longer life than the four days it was given. Most people with any interest in colour television could have spent some profitable hours studying it closely, but too many people wanted to do so to enable anyone to derive full benefit from it.

Mullard showed several applications of a transistor operating under 'avalanche' conditions. It then functions in a manner which can be likened, perhaps rather crudely, to a thyratron. The collector is operated at a high voltage so that holes flowing to the collector reach a high enough velocity to ionize atoms near the collector. The electrons produced by this process flow in the base circuit and these produce a bias tending to increase the action.

The device can be used to produce a sudden

*Mullard transistor oscilloscope.*



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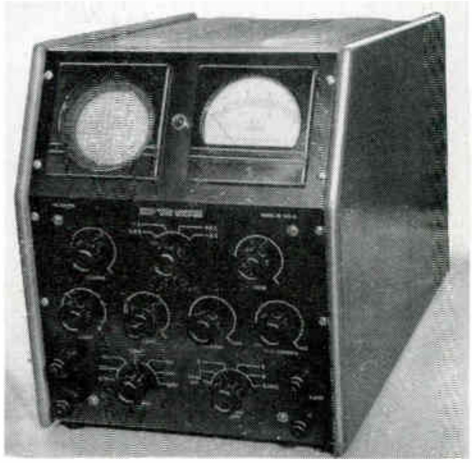
discharge of a capacitor. With a 70-V supply, the transistor can produce a current pulse of 100-mA amplitude and 0·05-$\mu$sec duration. The voltage is of 60-V amplitude and of more or less sawtooth waveform. A repetition frequency of up to 1 Mc/s is possible.

A use which the transistor may fill in the future was also shown by Mullard in an experimental oscilloscope using only transistors in the deflection and power-supply circuits. Operating from a 12-V battery, the consumption is about 6 W and the h.t. supplies of 65 V and 1·2 kV are provided by ringing-choke circuits. The Y amplifier has a gain of 32 dB and a response from 30 c/s to 50 kc/s. It is, of course, a simple instrument and in this is quite unlike the majority of modern oscilloscopes which seem to be getting more and more complicated. To a large extent this is due to the trend towards making them precision measuring instruments rather than merely waveform indicators, as so many early types were.

*Solartron type CD 523 " Solarscope".*

An example of a modern general-purpose instrument is the Cossor 1058. It has a 4-in. tube with post-deflection acceleration and the Y amplifier has a response extending from zero to 6 Mc/s with a gain sufficient to provide a deflection sensitivity of 0·25 V/cm. The timebase is either free-running or triggered and the X amplifier provides for a sweep expansion of up to five times. Both voltages and time calibration facilities are included.



*British Physical Laboratories Voltascope RS 900.*

The Solartron CD 523 is another general-purpose type with a bandwidth of zero up to 10 Mc/s at a sensitivity of 10 V/cm. The amplifiers have their gain stabilized by feedback and the timebase is of the modified Miller type with a velocity range of 10 cm/$\mu$sec to 1 cm/sec in seven steps.

A smaller instrument is the combined oscilloscope and valve voltmeter of British Physical Laboratories. The valve voltmeter covers d.c. and a.c. up to 500 V, while the oscilloscope has a $2\frac{3}{4}$-in. tube and a gas-triode form of timebase. Both are intended mainly for use at frequencies up to about 100 kc/s.

A much more specialized instrument is the Mullard L.140 which is designed for the measurement of pulse waveforms. A cathode-follower

*Furzehill oscilloscope type O 130.*



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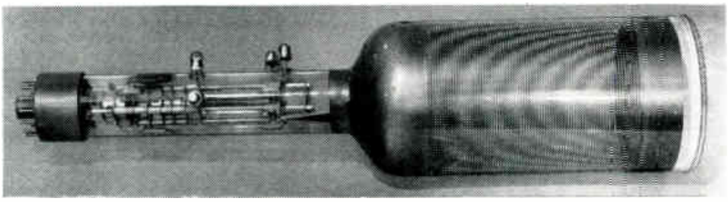
input probe is used and it can be biased off so that only the upper parts of a pulse waveform are passed, thus facilitating the accurate measurement of small *changes* of pulse amplitude. It is claimed that the cumulative error of time-display measurements does not exceed 3% for time intervals of 2 $\mu$sec to 150 msec.

An example of a very highly-specialized oscilloscope is the Cintel model, which is suitable for single-shot transient work. It has a tube with four post-deflection accelerators operating at up to 24 kV. There are no amplifiers and the signal is applied to the Y plates via a 72-Ω cable, the frequency response being maintained to 500 Mc/s, and the sensitivity is 50 V/in.

Among apparatus for use with the oscilloscope, the beam switch showed by Furzehill Laboratories is of interest. In effect, it converts a single-beam oscilloscope into a double-beam. It comprises a



*20th Century Electronics post-deflection accelerator tube with spiral accelerator.*

pair of amplifiers with cathode-follower input stages and a switching-voltage generator which may be synchronized by either input. The amplifiers cover 10 c/s to 5 Mc/s.

A noteworthy development in oscilloscopes is the increasing use of c.r. tubes with one or more post-deflection accelerators in order to secure a bright trace while retaining high deflection sensitivity. A prototype tube of this kind was shown by 20th Century Electronics. It is unusual in that the accelerator takes the form of a spiral high-resistance coating on the wall of the tube. Some 8–10 kV is applied across its ends with the result that the accelerating field increases uniformly with distance along the tube.

Signal sources are always important in test and measurement. Probably stimulated by the introduction of f.m. broadcasting on Band II, quite a few frequency-modulated signal generators were shown.

The Advance type 60 a.m./f.m. signal generator covers 4–225 Mc/s with a maximum output of 100 mV in 75 Ω. An internal source permits either a.m. or f.m. to be used and, by the addition of an external source, the carrier can be simultaneously modulated in both ways. The r.f. oscillator operates on fundamental frequencies

*Nagard delayed square-pulse generator, type 5001.*

and is followed by a tuned amplifier; the attenuator has a range of 100 dB.

The Airmec signal generator type 204 covers 2–320 Mc/s. Internal modulation at 1 kc/s is provided and can be either a.m. or f.m. Whichever is used, the other can be obtained simultaneously by employing an external source. The deviation on f.m. is up to 80 kc/s on the lowest frequency range and up to 320 kc/s on the highest. A crystal calibrator is included and the output is up to 0·2 V.

The Hatfield Instruments LE 250 B signal generator is intended for use with an oscilloscope display of the receiver output. It is designed for work on f.m. receivers in the 81–105 Mc/s range, but there is a coverage of 3–20 Mc/s for i.f. alignment. The carrier can be frequency-modulated by a 400-c/s sine wave with a deviation of up to 75 kc/s or a 25-c/s sawtooth with a deviation of 0·5 Mc/s or 1 Mc/s.

In other fields other waveforms are needed, and an example of quite a different form of instrument is the Nagard wide-range delayed

*Wayne Kerr video noise-level meter, type M 131.*



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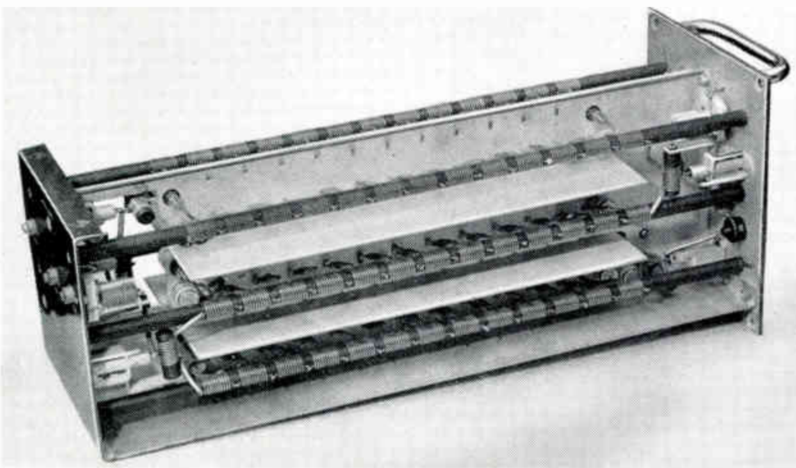
square-pulse generator. The main output is a pulse or square wave with a controllable amplitude calibrated to 1%, and with a pulse width variable from 0·2 μsec to 2 sec, but constant rise time. A second output is provided by a pulse which precedes that of the main output by an adjustable amount in the same range.

Cossor have a delayed pulse generator in which the delay is adjustable from 1 μsec to 11,111 μsec by decade switches. Marker 'pips' at 1, 10, 100 and 1,000 μsec intervals are provided.

In all forms of communication, the measurement of noise is of increasing importance and Wayne Kerr have produced a video noise-level meter. Basically, it comprises a video amplifier, with a bandwidth extending from 10 kc/s to 1·5, 3, 6 or 10 Mc/s, the upper limit being selected by a switch, and a mean-square detector. A calibrating oscillator is included.



*E.M.I. type 1 delay line for 0 — 30 Mc/s giving 0·6 μsec delay in steps of 0·1 μsec.*

The use of noise to measure intermodulation effects in multi-channel apparatus was demonstrated by the Post Office. The principle is, briefly, to apply noise equally to all channels except the one under test. The noise at the output of this channel is then a measure of the intermodulation products from the other channels.

Efforts are being made in several directions to extend the tuning range of klystrons. E.M.I. showed a reflex klystron (R 5222) using an external cavity resonator, a normal coverage being 8,400–10,100 Mc/s. By changing the resonator, however, the valve may be used from 5,000 Mc/s to 12,000 Mc/s. The power output is of the order of 60–100 mW.

Mullard have a method by which a tuning range of 500 Mc/s, with a mid-band frequency of 9,400 Mc/s, can be obtained from any low-power reflex klystron. Instead of using a mechanical plunger in a secondary cavity, this cavity is extended and provided with a ferrite ring. The effective length of the secondary cavity can be controlled by a magnetic field applied to the ferrite ring, which has the effect of altering the phase shift through the ring.

What amounts to a microwave wobbulator was demonstrated by G.E.C. It is intended for the alignment of wideband TR cells. The oscillator is mechanically tuned over a range centred on 10 cm and a linear timebase for the c.r. display is synchronized with it. The reflected wave from the test object is separated from the direct wave by a directional coupler and, after detection and amplification, it provides the Y deflection.

Phase measurements are of increasing importance in modern technique and Saunders-Roe showed an interesting phase meter covering the range of 50 c/s to 20 kc/s, with a phase range of 0–180°. The two input waves are squared in a circuit which automatically maintains a mark/space ratio of unity. The squared waves are fed to a pair of valves having a common load resistor. The resulting anode-voltage pulse depends for its width upon the overlap between the square waves and, hence, on the phase difference between the inputs. It is integrated and used to operate a voltmeter calibrated in phase angle.

Although computors are highly-specialized pieces of apparatus, in their details they function in the same way as any other piece of electronic apparatus, with one exception. They need a 'memory'. New methods of obtaining this are continually being exploited and the well-known grid of ferrite rings is one attractive way of obtaining a memory. Several examples were shown and it is essentially a low-impedance current-operated device. Plessey demonstrated an alternative which is voltage-operated. A barium titanate crystal in the form of a flat plate is used. It is coated on each side by a series of parallel conductors, the conductors on the two sides being at right angles. An elementary 'cell' is formed wherever two conductors cross. At low voltages, the response time is considerable, 1 msec or more but, at 100 V, it becomes as little as 1 μsec.



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# KLYSTRON CONTROL SYSTEM

By R. J. D. Reeves

(*E. K. Cole, Ltd., Malmesbury, Wilts*)

**SUMMARY.**—Wide-range tuning of a reflex klystron is not effected by simply manipulating one control, and therefore the embodiment of such a valve as the primary element of an automatic tuning system elevates the degree of the servo design problem. Manipulation of the controls must be constrained by consideration of oscillation strength, and this consideration constitutes a second error criterion. Accordingly, the paper introduces the concept of a 'control plane' to illustrate the klystron properties, and the automatic tuning problem is recast as one in two dimensions. One solution of this problem, to provide a.f.c. for primary radar, is described in detail.

Part 1 of the paper describes test equipment which presents the control plane on the face of a c.r. tube and maps either klystron mode areas and frequency contours or servo-trajectories on to the plane.

Part 2 describes a comprehensive a.f.c. system which takes cognizance of oscillation strength while searching for, or tracking the required frequency. A sampling technique for mode centring is introduced which affords minimum disturbance to the controls and provides a slightly better error criterion than mode peak finding. The mechanical tuning mechanism employs an automatic two-speed gear after the fashion of domestic radio receivers to provide exact and stable position setting. The separate problem of second-channel instability which is attendant upon the use of incoherent frequency discriminators has been successfully solved.

In Part 3 of the paper the complete circuit diagram is produced and the individual circuit functions described. Certain features such as the mode centre discriminator characteristic and the speed of the electronic tuning loop are the subject of analysis.

## Part 1—The Cartograph

### The Nature of the Klystron

THE reflex klystron is in universal use as a low-power oscillator in the centimetre wavebands, and the mechanism of its behaviour has been exhaustively discussed elsewhere[1].

To summarize, oscillation is sustained by mutual interchange of energy between a resonant cavity and a high-velocity electron beam passing through it. A negative electrode in the path of the beam reflects it through the cavity a second time, after which the electrons are collected. The electric field in the cavity modulates the velocity of the electrons as they pass through and results in electron bunching, these bunches causing further excitation of the cavity on the return journey. By suitable choice of reflector potential the beam can be made to present a negative impedance to the cavity and in this way sustain oscillation and permit a certain amount of r.f. power to be abstracted for use.

While the mechanism of it may be of considerable interest to an engineer committed to the use of such a valve, what directly concerns him is its quantitative behaviour as a circuit element; what are the controls and how are the frequency and level of oscillation related to them? Now the frequency is primarily determined by the dimensions of the resonant cavity, and some adjustment of these dimensions is assumed to be available as a tuning control. It is only necessary to pre-suppose that the condition for oscillation obtains, to overlook the whole problem of klystron control as a trivial one. But the governing condition is that the reflector shall be at a suitable potential, and the complication arises in that the optimum potential is not independent of the resonator frequency. Consequently, wide-range tuning requires joint manipulation of two controls and is not an elementary operation.

In addition to this the reflector itself constitutes a restricted tuning control, for although it is provided primarily as a means of presenting a negative conductance to the cavity, the beam admittance will, in general, be complex, and the natural frequency of the cavity can be pulled, to an extent depending on its $Q$. This important property raises the status of the reflector to that of the primary control in many applications, for it has just the attributes beloved by the circuit designer, namely direct control of frequency by a high-impedance electrode. A.F.C. systems employing klystrons often accept the restrictions of tuning range and general tolerances in order to maintain the somewhat artificial simplicity of using only this control.

### The Control Plane

With a view to describing a more sophisticated control system, it is convenient to geometrize the problem by studying the klystron behaviour in terms of a vector space associated with the controls. As the cavity dimensions and reflector potential are considered to be the only controls, the aggregate of all possible settings is identified with a plane referred to as the control plane.

Fig. 1 is a map of the regions of oscillation in this plane, sketched from a 723/AB klystron by observing the current developed by a crystal detector. It is seen that permissible reflector

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voltages to maintain oscillation form a set of disconnected intervals. These are the characteristic modes of the klystron, the name referring to the distinct states of the electron beam which can result in oscillation. Within these intervals the power output varies continuously, as shown by the section through the control plane drawn in Fig. 2.

Examination of these sketches confirms that use of either control alone will only permit a restricted tuning range before oscillation ceases, and over this range the power output will not be constant.

## Mode Mapping

To examine the modes in a quantitative manner, a simple instrument has been devised to present Fig. 1 on the face of a cathode-ray tube. The mechanical and electronic controls are associated with the X and Y directions respectively, and are scanned at different rates so as to produce a raster on the tube face which represents the control plane. The size of the raster is fixed but the amplitude of the control scanning is variable and modifies the area represented on the tube. Also the average value of the control settings can be altered to shift the origin of the display.

To delineate the mode regions the Z co-ordinate (beam modulation) is associated with oscillation strength, as indicated by detector current. That is to say, whenever the joint

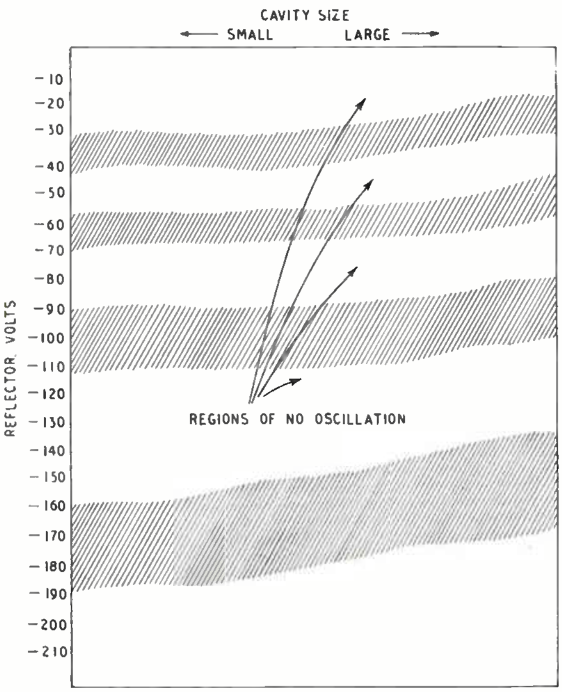
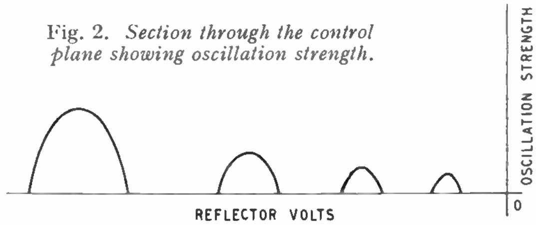



Fig. 1. *Oscillation regions in the control plane.*

control setting results in oscillation a brightening waveform is applied to the tube, causing the modes to appear as bright areas in the control plane.

In practice, there is hardly any need to have other than a fixed sweep on the cavity control, but it is very useful to be able to magnify and

Fig. 2. *Section through the control plane showing oscillation strength.*




shift the picture in the vertical direction so that each mode can be studied individually or, alternatively, the entire set viewed together. For this reason the average (d.c.) value of reflector voltage is monitored on a meter, and vertical shift and expansion controls provided. The speed restrictions associated with mechanical controls make it necessary to explore in the X direction rather slowly, so high-speed scanning is confined to the reflector and a long afterglow screen is employed.

This map-painting instrument presents the topology of the abstract control plane in a manner reminiscent of a p.p.i. display of real space, and the name 'Cartograph' has been given to it.

## Frequency Mapping and Trajectory Plotting

The mapping of crystal current only is of limited application but two interesting extensions of this basic process make the Cartograph a worth-while development tool whenever klystron behaviour has to be repeatedly examined.

First, it is a very simple matter to impress frequency contours on to the map, showing what joint control settings are necessary to generate a particular frequency. This is done by interposing an absorption cavity wavemeter between the klystron and its monitoring crystal. As a result there is a sharp notch in the transmission spectrum of the waveguide, so that the brightening waveform is interrupted whenever the klystron frequency coincides with that of the wavemeter, and a dark line is seen across the mode. The direction of these frequency contours is indicated in the sketch of Fig. 3, which reveals the restricted tuning range of the reflector control.

The second point is that the control trajectories of any klystron servo system may be plotted in the same plane.

The joint control setting corresponds to a point in the control plane and the locus of this point, as the servo performs some task, is of interest.



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It is particularly useful to examine the locus in relation to the mode topology and the frequency grid, and it is practicable to do this by preceding the control plot by a few cycles of mode map painting. Then the plot of the servo trajectory can be completed before the mode background has faded from the long persistence screen, and the relation between them observed.

### Cartograph Circuit

Fig. 4 is a schematic of the instrument complete with klystron and tuning mechanism, although in practice these may be integral with the servo system under observation and not attached to the Cartograph itself.

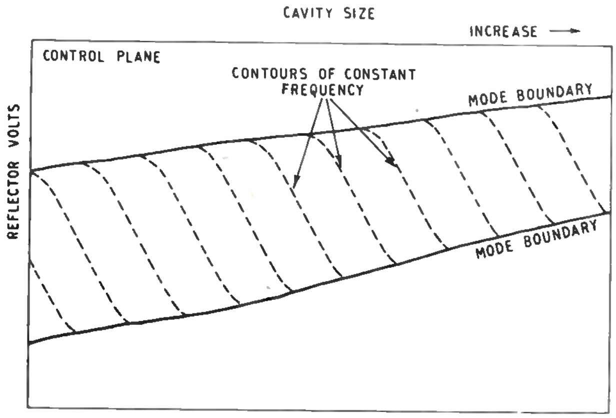


Fig. 3. *The frequency contours in the mode.*

For the map-painting process, the switches are in the positions shown and the motor scans the cavity continuously and deflects the spot in the X direction. The mean reflector potential is defined by the Y origin control and is monitored by a voltmeter, this reading corresponding to the horizontal centre line of the display. Superimposed on this potential is a sine-wave scan at a frequency of about 1 kc/s, which is also used to deflect the tube in the Y direction. The proportion of the a.c. scan that is actually fed to the reflector can be varied by the Y expansion control. The crystal-current variations resulting from scanning the reflector through several modes of oscillation are passed through a video amplifier and applied to the tube as a brightening waveform.

For the trajectory plotting feature, the relay S/3 reverses all the switches and the klystron controls are taken to the external control system. X deflection on the tube can still be performed by the cam monitor potentiometer but no corresponding facilities exist for transferring the d.c. reflector potential to the Y plates of the tube. This difficulty can be circumvented quite conveniently by leaving the same a.c. scan on the tube but now observing the instants of voltage coincidence between the scan waveform and the external reflector potential and marking them by brightening the trace. This guarantees that on the face of the tube the co-ordinates of the

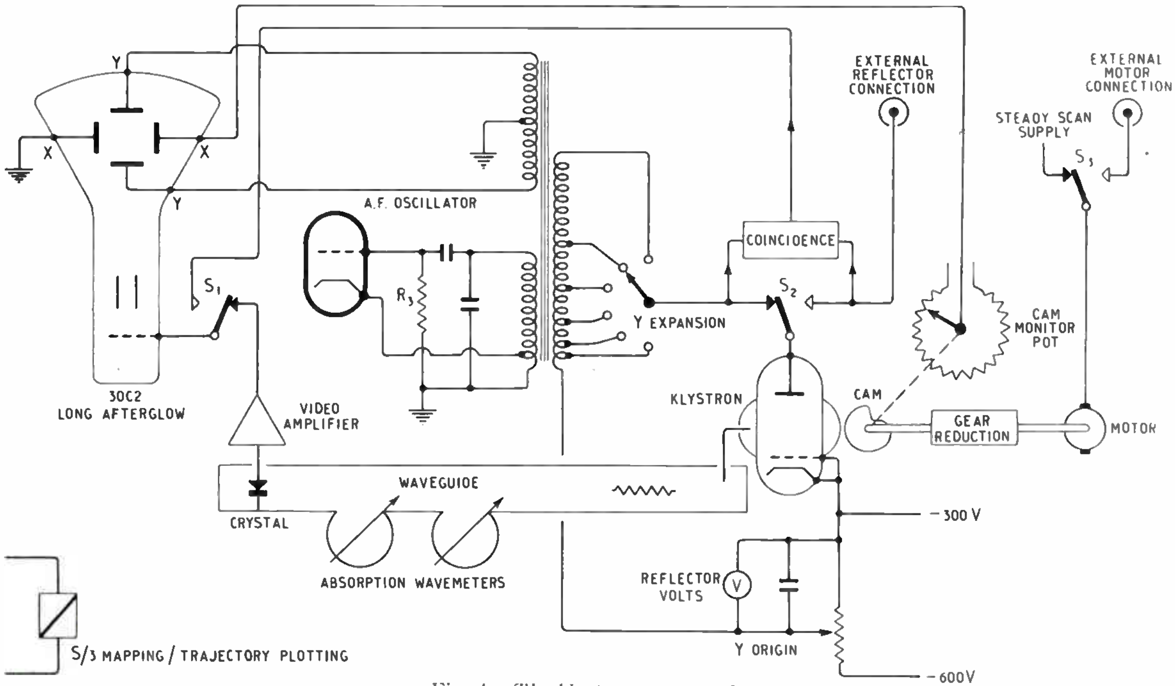


Fig. 4. *The klystron cartograph.*

trajectory arè precisely the same as for the crystal current map, and the superposition of the two pictures on the long persistence screen will be a faithful presentation of the modes and servo trajectories in the ground field of control settings.

The design of the voltage-coincidence circuit presents no difficulties if it can be assumed that the scan waveform always rapidly traverses the observed reflector potential; i.e., coincidences are brief. Then a trigger pulse can be developed to fire a blocking oscillator producing a brightening pulse.

Examples of the two distinct displays produced by the Cartograph are shown in Figs. 5 and 6. The first of these maps shows one mode with a frequency contour impressed, and the second a typical control trajectory in that mode. The long-persistence screen enables these two displays to be superposed.

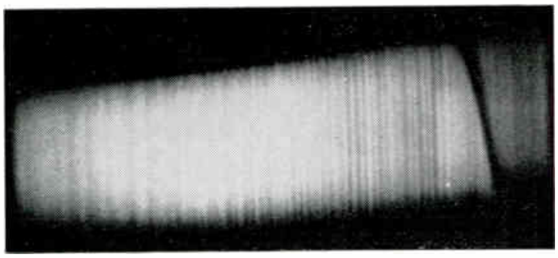

Fig. 5. *Mode map.*

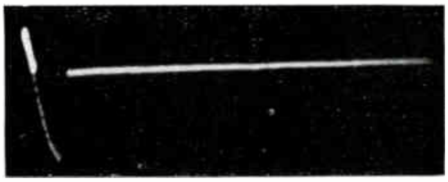

Fig. 6. *Control trajectory.*

## Part 2—Comprehensive A.F.C.

### The A.F.C. Problem

Where the centimetric wavebands are used for, say, radar transmission, it will be appreciated that the width of the channel spectrum is a very small percentage of the actual frequency radiated and the requirements for local-oscillator stability in the receiver are severe. However, if the degree of mistuning in the i.f. amplifier can be measured and fed-back degeneratively to the local oscillator, then the stability requirements are transferred to the error-measuring circuit at the i.f. and, at this frequency, they can easily be met. But the usual discriminators such as the Travis, Foster Seeley, Weiss, only provide a narrow region of frequency discrimination, outside of which little or no tuning error is indicated and until the i.f. beat note drifts into this region the a.f.c. loop will not be able to bring the local oscillator under control. In other words the presence of a frequency control loop alone is no guarantee of correct tuning unless means are provided to 'capture' the local oscillator at whatever frequency it initially sets itself. To make the oscillator intrinsically stable enough to stay within the capture region is virtually as stringent a requirement as keeping within tolerable tuning error without a.f.c. Inevitably the concept of a 'searching' local oscillator presents itself, whereby the oscillator is driven or cyclically drifts through a certain frequency spectrum until capture is effected. This complication, coupled with the complexity of correctly tuning a reflex klystron oscillator (as discussed in Part 1), tends to make the a.f.c. system occupy a disproportionate amount of both the radar unit and the attention of the designer.

It is a point to be decided in the initial stages of the development whether to make the a.f.c. as elementary as possible and in deference to this make the local oscillator (and transmitter) as stable as possible, or to go for completely comprehensive a.f.c. and relax the restrictions elsewhere. It is the author's contention that the comprehensive system to be described here is sufficiently compact to warrant adoption in many types of radar.

### The Control System

Fig. 7 is a block schematic of the a.f.c. system referred to, which provides wide-range search and frequency control, and at the same time maintains the klystron controls at mode centre. The system is capable of locking to either of the two local oscillator channels which generate an i.f. beat, and it permits stabilization of klystron supplies to be dispensed with.

The equipment was designed for a primary radar in which a sample of the radiated signal is directly available for the frequency discriminator and there is therefore no noise problem, but this is not an essential restriction.

The output of the frequency discriminator and of the time discriminator are the source of error signals in the servo system and the Miller integrator and motor-control valves are the control points. In the block diagram the lock-on relay is shown closed and the time discriminator output (mode-centring error) is fed to the motor control, while the frequency error is fed to the reflector. Although the error signals are not coupled at all inside the control system, each error is a function of both controls, so the two loops are not independent and the system is properly described as a two-dimensional servo, which can be conveniently discussed in terms of the control plane.

In the absence of an i.f. beat the lock-on relay



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drops out and diverts mode-centring error signals to the reflector, while a residual search bias keeps the motor scanning the cavity. In this condition there is no output from the frequency discriminator. The search trajectory in the control plane is therefore the line of the mode centre, whereas when the system locks on, the controls are constrained to be on one of the two frequency contours which generate an i.f. beat. The intersections of these contours with the search trajectory represent points at which both error signals are nil, and the control system can come to rest on either of them. It is assumed to be of no consequence whether the local oscillator adopts a frequency above or below that of the transmitter.

## Mode Centring by Time Discrimination

The block schematic Fig. 7 is actually a plan of a working demonstration model. The waveform insets represent c.r.t. displays associated with the mode-centring process, and the relation between them is shown in Fig. 8. A single cycle of a sine wave (loosely referred to as a sinusoid) is superimposed on the reflector potential and the crystal-current variations observed; the waveforms (2) or (3) are obtained depending on whether reflector voltage or time is used as a display base. The object of doing this is to project the mode shape (2) on to a time scale where mode-centre displacement can be more easily determined. The mode mapping (3) is actually a double representation since the sinusoid traverses the mode twice, and the centre half of the sinusoid would suffice for this process but no advantage would accrue, and the waveform (1) is more easily generated. Now the sinusoid is skew symmetric about its centre point $t_0$, and the product of (1) and (3) will also be so if the mode map is symmetric about $t_0$. The average value of this product will then be zero but, if the mean reflector potential is not at mode centre, a greater part of the mode map will appear on one side of $t_0$ on the time scale and then the product waveform will have a d.c. content with magnitude and sign related to those of the reflector displacement. This constitutes the error signal. Fig. 8 is drawn with a small misalignment of the reflector and it is seen that the majority of the mode is projected into the second half of the mapping period. The corresponding c.r.t. displays are shown in Figs. 9 and 10.

The sinusoid actually performs a gating function in the time discriminators and not a genuine multiplication, so the skew waveform is virtually a truncated sinusoid in the demodulation process, but this is equally suitable for the purpose.

## Features of the Mode Projection Process

If the sinusoid did not terminate after one cycle but persisted continuously, and if it were of very

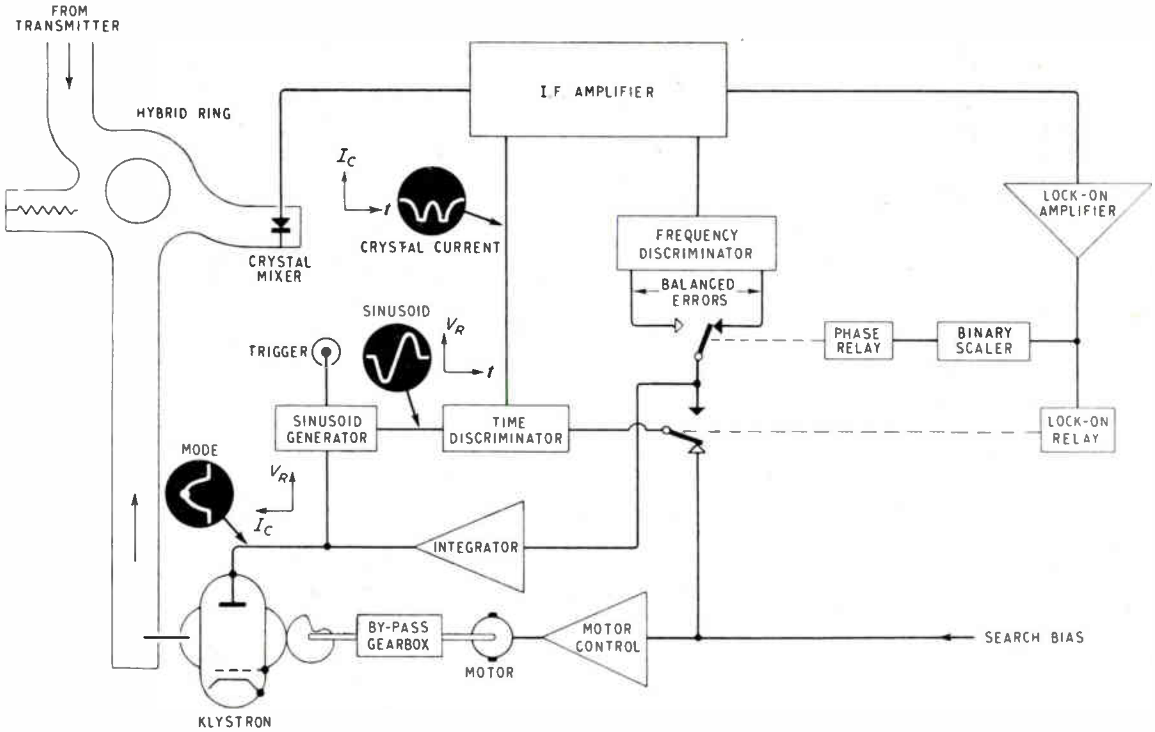


Fig. 7. *Klystron control system for a.f.c.*



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small amplitude so that it explored only the immediate neighbourhood of the existing reflector setting, then the output of the time discriminator (now more correctly described as a phase-conscious rectifier) would be an indication of the magnitude and sign of the slope of the mode at that point, and the servo could be made to home on to a point of zero slope. This is the process employed in some form by all previous klystron control systems in which mode centring is attempted. In this system, however, the sinusoid amplitude is about two mode widths

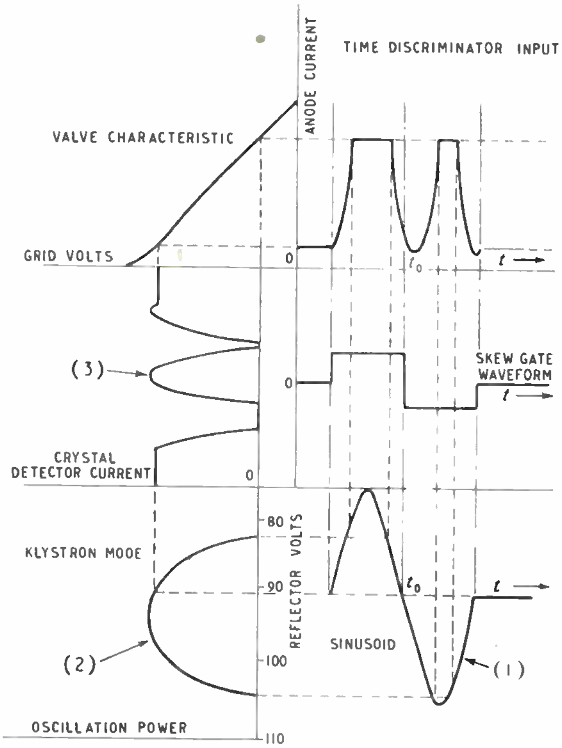


Fig. 8. *Sinusoidal projection of mode on to time scale.*

peak-to-peak and between mapping times there are no perturbations on the reflector from this source. The mapping times can be very short and can be distributed arbitrarily so that, although reception has to be abandoned completely at these moments, this restriction is more apparent than real. The mode-centring loop becomes in fact a sampling servo and the necessary rate of sampling depends on the highest error frequency required to be handled, which is likely to be very low indeed. The sampling rate could therefore be correspondingly low but, in practice, there is usually a dead time in the radar at the end of every repetition period and it is convenient to initiate the sinusoid excursion there. Alternatively, if the duty cycle of the sinusoid is low,

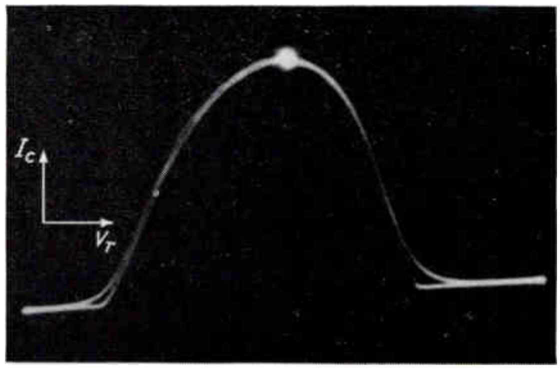


Fig. 9. *Klystron mode.*

say, less than 0·01, then it may be run asynchronously with the transmitter and that proportion of received signals lost.

The use of a large-amplitude sinusoid confers two advantages which characterize this control system, the most significant one being the improved mode pull-in performance. Since error signals are developed even if just the peak of the sinusoid is encountering the mode, the reflector will be pulled in to the mode centre. Using a sinusoid which is two mode widths peak-to-peak, the pull-in range may be three times greater than a system which requires the mean reflector potential to be actually on the mode before centring occurs. The capture range, which is so important at the time of switching on, has therefore been usefully extended.

The other feature is that peak power is no longer the servo target but rather the discriminator measures displacement from the centroid of (weighted) mode area. If the mode is symmetrical no difference in rest position results but, if the mode is appreciably asymmetrical, the reflector will adopt a position from which it is better able to cope with transient disturbances in either direction. This would seem to be a more useful criterion than that of peak power.

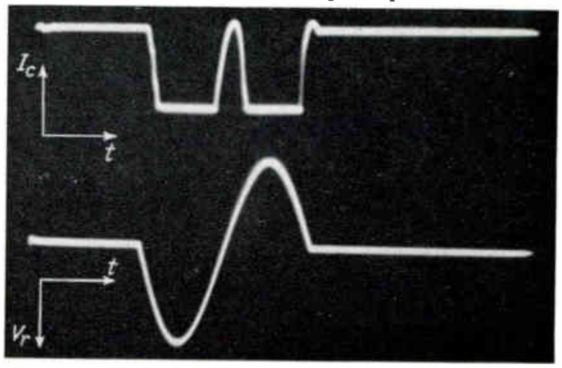


Fig. 10. *Sinusoid deviation and consequent crystal current variations.*



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## Frequency Discriminator

In principle, the frequency discriminator is quite conventional but the design is governed by the fact that the i.f. is not continuously available but is sampled when the transmitter fires. The result is that either a clamp or an integrator is required to store the output during the space period, and also the signal incoming to the discriminator is not a spectrum line but a frequency distribution of sin $x/x$ form. Therefore, the overall discrimination characteristic is not the frequency characteristic of the discriminator itself but the product of the discriminator characteristic and the incoming pulse spectrum as a function of the misalignment of the two. In this situation it does not follow that a small peak separation in the discriminator corresponds to high error sensitivity for, if the pulse energy is distributed over a wide band, the discriminator characteristic tends to be swamped. Moreover, unless the peak separation is comparable to the width of the principal part of the pulse spectrum it is quite possible for the a.f.c. to lock to a minor peak.

In this particular design a half-microsecond pulse has to be catered for, and a peak separation of 5 Mc/s is used in the discriminator.

A buffer amplifier is interposed between the discriminator and the pulse-stretching circuits in order that the design of the discriminator is not complicated by excessive loading effects. The error output is available in either polarity according to the state of a phase relay, so that ambiguity of sign arising from ignorance of the phase of the i.f. can be resolved. A separate d.c. output is developed whenever a signal appears in the discriminator, and this constitutes a lock-on signal.

## Lock-on Procedure

The presence of the lock-on signal indicates that the search has brought the local oscillator close enough to the required frequency to be put under the control of the frequency discriminator and the change-over from searching to frequency tracking is effected by a lock-on relay. In this design, the chief function of this relay is to divert the mode-centring errors from the reflector to the motor circuit and swamp the search bias with mode-error signals. The reflector is left to handle the frequency-error signals which appear at the same time as the lock-on voltage.

The search–follow transition is therefore well defined, and this fact enables a simple relay scaling circuit to be employed to combat a type of instability which threatens all automatic systems in which both first and second channel frequencies fall within the swept spectrum. In a conventional (incoherent) frequency discriminator, increments of local-oscillator frequency are preserved in magnitude but are ambiguous in sign and, consequently, a control loop which is designed to stabilize at the i.f. on one channel will evade it on the other. Such evasion throws the pulse spectrum to the edge of the i.f. channel, at which point the lock-on signal disappears and the reflector control recentres itself in the mode in accordance with the normal search condition. But this, of course, is the same control setting as that which originally brought about the lock-on, so the unstable cycle repeats indefinitely. However, by relating a loop-phase reversing relay to the lock-on relay by a scale of two, successive lock-on operations find alternate loop phases existing and, if the first lock-on is not stable, the second one will be. In this way the control system will settle the klystron on the frequency above or below that of the magnetron indiscriminately, depending which is first encountered in the search cycle. This procedure not only circumvents the difficulty of ignoring the unstable channel during the search but is likely to shorten the searching time.

Discussion of the homing trajectory in the control plane is deferred until the gearbox features have been described.

## Mechanical Features

The choice of tuning motor and the design of its associated mechanism are of central importance for this unit may well govern the bulk, complexity and reliability of the whole equipment. Although there is no appreciable load to consider, precise position control is required and this is one reason why speed control of the motor would be desirable. But a mechanical system which incorporates local tachometer feedback is likely to be bulky and demand a substantial power output from the control circuit. Simplicity is best maintained by departing from linear methods and using a constant-speed motor with on-off control by a polarized relay. Unfortunately, a gear reduction that results in acceptable search is not compatible with that required for fine tuning, and it is necessary to correlate a gear change with the lock-on relay so that both fast search and a stable control loop may be realized. The way that this is achieved here is a development of a device featured for many years in domestic radio sets, and depends on having a unidirectional search (with a quick return or flashback). The full gear reduction for low-speed tuning is available only for a limited interval of movement, beyond which a section of the reduction is by-passed and coarse tuning provided. But the low gear interval travels with the by-pass drive and can always be entered by reversing the motor. The effect is that the motor approaches



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its final rest position at high speed and overshoots. The error signals reverse the motor which then enters the low-gear interval and returns to the rest position at greatly reduced speed. This interval has to be at least as wide as the initial overshoot but, apart from that, the extent of it is not important. Twice the overshoot is a reasonable size to adopt. Continuous tracking in one direction would, of course, cause a momentary change into high gear periodically, but this is tolerable and in any case is not anticipated as typical.

The two tuning speeds are chosen quite independently of each other according to the search speed requirements on the one hand and the maximum desirable loop gain on the other, and the transition from high speed to low is performed at the moment of reversal when the mechanism is stationary, so the homing approach is essentially smooth. Changing from low speed to high normally occurs shortly after unlocking when the servo has started searching and the load then suffers a velocity step. In fly-power position where this impact is not severe, the by-pass type of gear box has many applications because of its simplicity both in construction and in functioning without any auxiliary information being required. It would, for instance, be equally applicable in a search–follow system in which the lock-on transition is not well defined by a relay operation.

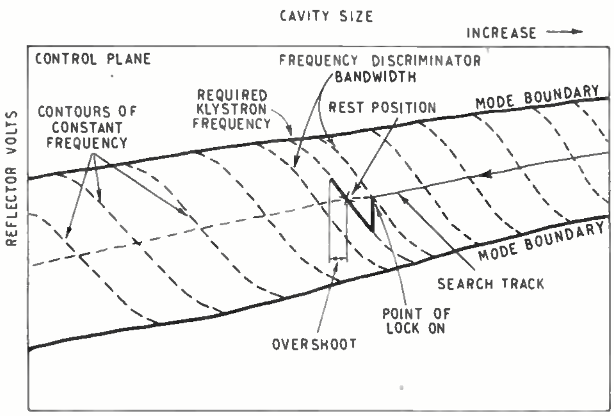


Fig. 11. *The homing trajectory.*

Unless the search were unidirectional the mechanism would have to traverse the low-gear interval at each end of the scan and this would be a time-consuming and pointless process. The difficulty is avoided by having a flash-back mechanism such that the tuning piston is returned to the start from the end of every search scan. This, in fact, is the simplest search procedure, for the mechanism must not be reversed by local switching because of the loop phase ambiguity which then arises when the system locks on. A two-way search requires limit switches which reverse the search bias in the control unit, with the attendant hazard in the assumption that the control system is functioning as soon as the motor is switched on.

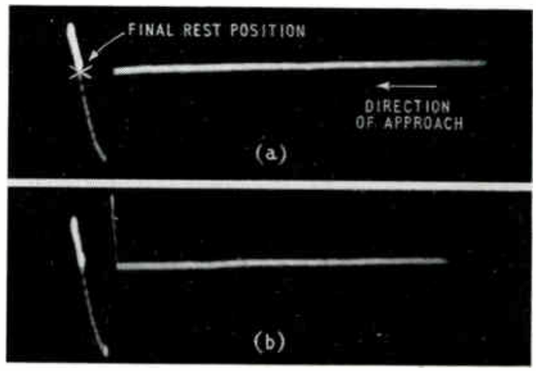


Fig. 12. *Approach with loop phase; (a) correct, (b) incorrect.*

The present quick-return mechanism is an entirely self-contained unit which can be run independently of the control system for the purpose of testing, and of course in conjunction with many different types of control system.

## The Homing Trajectory

The behaviour of the complete system is best described with reference to the homing trajectory, shown in Fig. 11. When the equipment is first switched on, searching starts as soon as the control system warms up, and mode pull-in occurs as soon as the klystron warms up and crystal current is available. Thereafter, the search trajectory is the locus of mode centre, and centring is maintained even during the mechanical flash back. This condition persists for a few minutes before the transmitter comes on, after which it is possible to develop an i.f. beat when the klystron is brought to an appropriate frequency. The two channels are relatively close so, if the klystron is ascending the frequency spectrum, it is more likely to encounter the low channel first and lock on to that. A lock-on voltage is developed as soon as the search trajectory encounters the frequency line corresponding to the edge of the frequency-discriminator band, and immediately the reflector is put under the control of the discriminator. The subsequent motion depends upon whether the frequency-control loop phase is correct or not; if it is incorrect, the reflector will drive away from the required frequency contour (upwards in Fig. 11)



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until the lock-on signal disappears, and then re-set itself on the search trajectory. Immediate relocking occurs with the phase now corrected. The speed of the reflector control is fast compared with that of the piston so that these motions appear as a vertical movement in the sketch.

With the loop phase correct the reflector jumps to the required frequency contour and from this moment the i.f. is held. There is at this point, however, a mode-centring error, so the motor (supplied with this error signal) continues to turn in the same direction to annul the error. The reflector loop constrains the joint control setting to be always on the frequency line, which is therefore the new trajectory of the motion. The intersection of this with the search trajectory is the point where both error signals are zero and therefore the final rest position, but on the first approach the motor will overshoot because the mechanical by-pass is still in operation. The first reversal, however, engages the final gear reduction and the controls move back to the rest position with adequate loop damping. Fig. 12 (a) is a photograph of the homing trajectory when the loop phase is correct for the channel that is first encountered, whereas Fig. 12 (b) shows the adapting transient undergone when the phase is unsuitable on the approach.

If the transmitter signal disappears, the servo will unlock and start to travel along the search trajectory from its rest position, but motion will be slow at first until the low gear interval has been traversed, and this is advantageous in that, if the interruption is only momentary, the system will relock and return instead of escaping into an unnecessary search cycle.

*(To be continued)*

# LINE TRANSMISSION CIRCUITS

## *Effects of Longitudinal Voltage and Current*

**By E. D. Fitton, B.Sc. (Eng.), A.M.I.E.E. and R. E. Howland**

*(Engineering Division, B.B.C.)*

**SUMMARY.**—This article describes in some detail the means by which longitudinal currents and voltages are introduced into transmission circuits and associated apparatus. The effects of these currents and voltages, and methods by which these effects may be eliminated or reduced, are discussed.

It is necessary to start by defining four terms which will be used frequently:—

1. A 'Longitudinal Current' flowing in each wire of a pair of wires may be defined as half the algebraic sum of the instantaneous currents flowing in the wires at a given point.
2. A 'Circulating Current' flowing in each wire of a pair of wires may be defined as half the algebraic difference of the instantaneous currents flowing in the wires at a given point.
3. A 'Longitudinal Voltage' is defined as half the algebraic sum of the instantaneous voltages between each wire of a pair of wires and a third conductor at the given point. (The third conductor is usually earth.)
4. A 'Circulating Voltage' between the two wires of a pair may be defined as the algebraic difference between the voltages between each wire and a third conductor (usually earth) or alternatively as the product of the current flowing through, and the magnitude of the impedance between the pair at that point.

If, in order to determine the magnitude of the circulating voltage at a given point, an impedance is connected across the pair, then the magnitude of the 'open-circuit' voltage may be determined by Thévenin's theorem.

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Consider the general case of current flow in the light of (1) and (2) above. Any current flowing may be represented as (a) a circulating current, $I_c$, flowing in opposite directions in the two wires, and (b) a longitudinal current, $I_0$ flowing in the same direction in the two wires. The currents $I_c$ and $I_0$ may consist of the instantaneous sum of several waveforms and, further, each may consist of a wanted and an unwanted component.

The general case of voltage, as in (3) and (4) above may be represented by an equipotential voltage, $V_0$, between each wire and the third conductor and a voltage, $V_a$, between one wire and the third conductor equal in magnitude but opposite in sign to a voltage $V_b$ between the other wire and the third conductor. The longitudinal voltage $V_0$ and the circulating voltage $(V_a—V_b)$ may each consist of the instantaneous sum of several waveforms.

In general, therefore, a pair of wires may have a wanted signal voltage between them and, in addition, an unwanted signal voltage between them, also a wanted and an unwanted longitudinal voltage may be present between each wire and a third conductor.

It will be seen that the concepts of longitudinal current and voltage are closely linked. It is



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convenient, however, to have established them both, as some problems involving their consideration may be solved more easily by one concept than the other.

It will now be shown that if circulating current is present with longitudinal current then, in general, a longitudinal voltage exists.

Fig. 1 represents a small length $\Delta L$ of a pair of wires (A and B) distance $L$ from a generator connected to A and B, the primary constants of the pair being uniform over the length $\Delta L$.

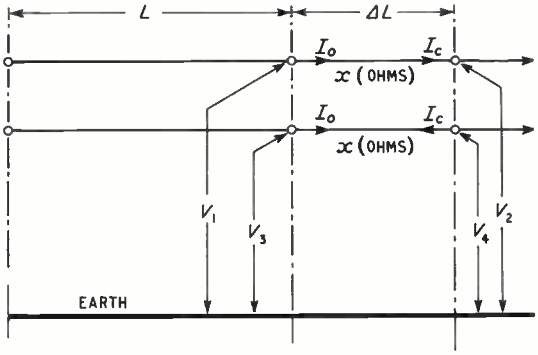


Fig. 1. *Pair of wires A and B near earth.*

Let $I_c$ be the circulating current in the section, the resistance of the section of wire be $x$ ohms, (neglecting inductance, capacitance and leakance) and let $I_0$ be the longitudinal current present. Further, let voltage $V_1$ to earth and $V_3$ to earth (at the entrance to $\Delta L$) be identical but opposite in sign; i.e., by definition, at this point no longitudinal voltage exists. Consider now the voltages $V_2$ and $V_4$ to earth (at the end of $\Delta L$.)

$$V_2 = V_1 - (I_c + I_0)\,x \qquad \ldots \qquad \ldots \qquad (1)$$

$$V_4 = V_3 - (I_0 - I_c)\,x \qquad \ldots \qquad \ldots \qquad (2)$$

Now $\quad V_3 = -V_1$

Hence $\quad V_4 = -V_1 - (I_0 - I_c)\,x$

$$= -V_1 + (I_c - I_0)\,x \qquad \ldots \qquad (3)$$

From (3) $\quad -V_4 = V_1 - (y_c - I_0)\,x \qquad (4)$

Comparing (1) and (4) it will be seen that $-V_4 \neq V_2$ and hence at $L + \Delta L$ a longitudinal voltage exists.

Let us consider how longitudinals may be introduced into a pair of wires. Fig. 2 shows how this occurs by electromagnetic coupling either with the pair itself or with a circuit element connected to the pair.

Referring to Fig. 2(a) G is a conductor adjacent to the pair AA′, BB′ and is carrying a current $I_g$ in the direction shown. The flux lines $f_1$, $f_2$, etc. due to $I_g$ cutting AA′ and BB′ produce currents $I_{0a}$ and $I_{0b}$ of magnitude increasing with $I_g$ and decreasing with $d_1$ and $d_2$ the distance of AA′ and BB′ respectively from G. It will be seen, therefore, that if the distance $d$ between $AA'$ and BB′ is small with respect to $d_1$, then $d_2 \rightarrow d_1$ and therefore $I_{0a} \rightarrow I_{0b}$. Further, if AA′ and BB′ are transposed along their length, this also tends to make $I_{0a} = I_{0b}$.

Clearly, for current to flow along A′A and B′B there must be a return path A to A′ and B to B′. In general this is via the admittance to earth from A and A′, similarly from B and B′.

Referring to Fig. 2(b) assuming that $T_1$ is a perfect transformer balanced to earth, and that $Y_a$ and $Y_b$ are the admittances to earth at A and B of the pair AA′, BB′ and that adjacent to $T_1$ is a source of electromagnetic flux S. The flux linkages $f_1$, $f_2$, etc. from S to the secondary of $T_1$ are such that the induced voltage per turn progressively decreases along the length of the secondary winding. Consider C, the centre point of the winding having admittance $Y_c$ to earth. The induced voltages from C are $V_1$ to A and $V_2$ to B; and clearly $V_1 \neq V_2$.

For a normal pair of wires in good condition, $Y_a$ is approximately equal to $Y_b$ and, therefore, the voltages at A and B to earth are approximately equal to $V_1$ and $V_2$ and as $V_1 \neq V_2$, by definition longitudinal voltages exist at A B due to induction from S. It will be seen that, in the cases where electromagnetic introduction of logitudinals occur, the source impedance is low compared with the path followed by the induced currents via earth admittances. Hence, it is convenient to consider such induction as emanating from a constant-voltage source.

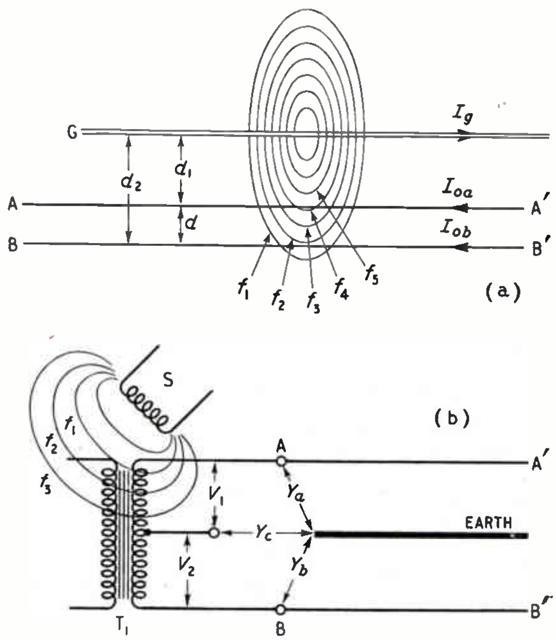


Fig. 2. *Pair of wires near a conductor G carrying current (a) and wires fed from a balanced transformer (b).*



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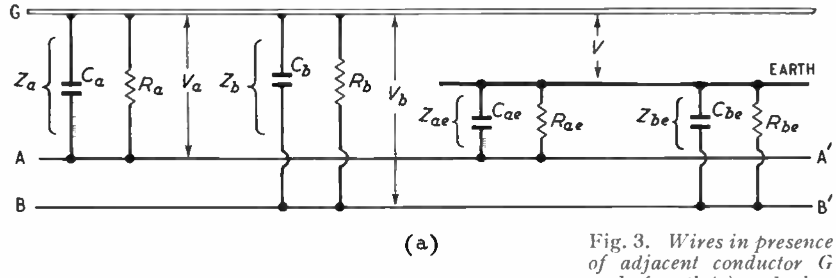
Let us now consider the introduction of longitudinals by electrostatic coupling, either with the pair itself or with a circuit element connected to the pair.

Fig. 3 (a) shows a conductor G adjacent to pair A B and having a potential $V$ with respect to earth and negligible current flow along its length. Consider the section of A B chosen to have impedance $Z_a$ between A and G, $Z_b$ between B and G, $Z_{ae}$ and $Z_{be}$ to earth respectively.



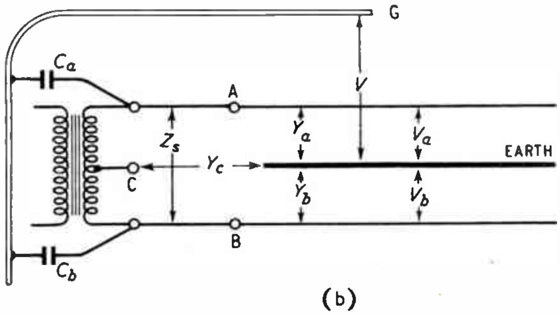




Fig. 3. *Wires in presence of adjacent conductor G and of earth (a) and when a transformer is introduced (b).*

Consider the voltages $V_a$ and $V_b$ from G to A and B

$$V_a = V\frac{Z_{ae}}{Z_a + Z_{ae}}$$

$$V_b = V\frac{Z_{be}}{Z_b + Z_{be}}$$

It will be seen that $V_a$ and $V_b$, though possibly of equal magnitude, will be of the same sign and, therefore, by definition a longitudinal voltage exists at this point. Further if $Z_a \neq Z_b$ and/or $Z_{ae} \neq Z_{be}$ then $V_a \neq V_b$, the conditions of an induced unwanted signal voltage.

Fig. 3 (b) shows the same transformer $T_1$ as in Fig. 2 (b) connected to pair A B. In this case, however, a conductor G is adjacent to $T_1$ having voltage $V$ with respect to earth and capacitance $C_a$ and $C_b$ to the ends of the secondary winding as shown.

Assume again admittance $Y_a$, $Y_b$ and $Y_c$ and further, that the secondary-winding impedance $Z_s$ is equally divided at C.

Due to $V$ a voltage drop $V_a$ will exist across $Y_a$ which is now part of the potential divider $\frac{1}{j\omega C_a} + \left\{\frac{1}{Y_a} \text{ in parallel with } \frac{1}{Y_c} + \frac{Z_s}{2}\right\}$ and, similarly, a voltage drop $V_b$ will exist across $Y_b$ and will be of the same sign as $V_a$ with respect to earth. Therefore by definition a longitudinal voltage exists.

The electrostatic introduction of longitudinals is, in the main, by the capacitance (leakance normally being negligible) between the pair of wires (or apparatus connected to it) and the generating source.

In general, this capacitive susceptance will be very much smaller than the earth admittances. It is convenient, therefore, to consider such inductions as emanating from a constant current source.

We will now consider the practical implication of longitudinal voltages and current in relation to a pair of wires over which it is desired to transmit a signal comprising a complex waveform from a generator to a distant load.

Fig. 4 shows such a transmission circuit connecting a generator with internal impedance $Z_s$ feeding a resistive load $R$ via a pair of wires AA′, BB′.

This is the ideal case and the rest of this paper shows how far practical circuits fall short of this ideal and some methods that may be adopted to overcome errors introduced by longitudinals.

Fig. 5 shows the circuit of a pair AA′—BB′ connecting a generator G to a load L. (G incorporates an output transformer $T_1$ with

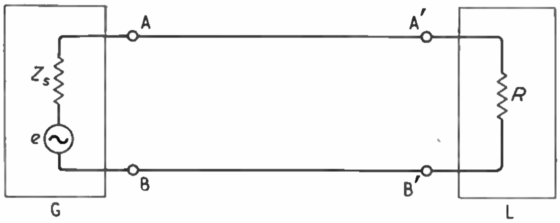



Fig. 4. *General form of load L connected to a generator G.*

generator $E_a$ in the primary and L is the first stage of a triode amplifier with an input transformer $T_2$.) The pair of wires has imposed upon it, due to an external coupling, a longitudinal current $I_0$, an unwanted circulating current $I_u$, and due to the e.m.f. of generator G (produced by $I_p$ in the primary $T_1$), the wanted signal current $I_a$.

The current $I_u$ flowing through $T_2$ will produce an unwanted signal at the grid of the valve. $I_0$ may be represented to have been produced by a generator $E_0$ of e.m.f. $e$ connected to earth via an impedance $Z_0$ to the centre point of the secondary winding of $T_1$. We may conveniently represent the inter-winding capacitance of $T_2$ as lumped in $C_1$ and $C_2$ at either end of the windings.

The return path to earth at A′ B′ is via the impedance $Z_a$ and $Z_b$ to earth of the input terminals of L (other paths to earth, of course, exist along the pair). Consider impedance $Z_b$; this is equal to $1/j\omega C_2$ (the parallel leakance being neglected).

The impedance $Z_a$ (neglecting minor quantities) is made up of a parallel path $(j\omega L_p + 1/j\omega C_2)$ and $(j\omega L_s + 1/j\omega C_1)$ where $L_p$ and $L_s$ are the primary and secondary shunt inductance.

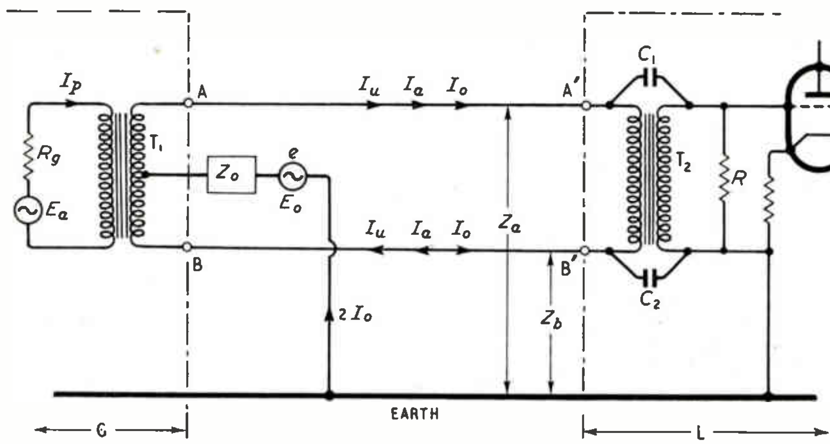



Fig. 5. *Line connected to generator and valve amplifier through transformers.*

Clearly, $Z_a \neq Z_b$ and therefore the voltages across them due to $I_0$ flowing through them are not equal. Hence, due to $I_0$, a further potential difference is established across the input terminals of the load which will cause a further unwanted voltage at the grid of the valve.

It will be seen, therefore, that even if $I_u$ is not present, $I_0$ will cause an unwanted voltage in the load.

A similar analysis will reveal that an equivalent state of affairs exists at the generator end.

Hence, it may be said that a longitudinal current (or voltage, by a similar analysis) induced in a transmission pair will cause an unwanted signal to appear at the grid of a valve amplifier connected to that pair. The effect would be even more serious if no input transformer were present where in general $Z_b = 0$ and $Z_a$ is of the order of one megohm.

Obviously the magnitude of the unwanted signal will depend upon the value of $I_0$ and the difference between $Z_a$ and $Z_b$. (Similar considerations apply when determining the unwanted signal added to the generator output.)

It is impossible completely to isolate a pair of wires and the apparatus connected to it from other current or voltage-carrying conductors. Therefore, to keep unwanted signals to a minimum—apart from screening and twisting the pair to reduce the magnitude of induced longitudinals—it is necessary to make the apparatus terminal-to-earth impedances balanced to the best possible limits.

This can be achieved to very good limits by the use of the 'balanced line transformer' or 'repeating coil'.

The essential features of these are an earthed electrostatic screen interposed between the primary and secondary windings; and the construction of the primary windings in two halves. These are made in such a manner that if the windings are connected series-aiding (for circulating current) the potential gradient with respect to the junction, in each winding, is virtually the same when a longitudinal voltage with respect to earth is applied across their outer terminals.

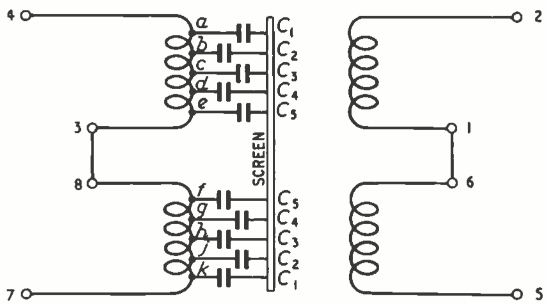



Fig. 6. *Arrangement of windings and capacitance distribution in transformer.*

Fig. 6 shows the capacitance distribution in such a transformer.

The 'line windings' 4-3, 8-7 have equal capacitances $C_1$, $C_2$, $C_3$, etc. as shown. Now between points 'a' and 'b' the resistance, inductance and capacitance are identical with those between points 'j' and 'k', et seq, until points 'e' and 'f'; let us consider the passage of longitudinal current through the line winding. As shown before, the path of such a current entering 4 and 7 is through the earth admittances at 4 and 7.



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Due to the equal distribution of primary constants in windings 4-3, 8-7, it will be seen that points 'e' and 'f' will be equipotential with respect to earth and the current flow through each related turn will be identical in magnitude but opposite in direction, therefore, the resultant magnetic flux will be zero; i.e., no voltage will be induced in the secondary winding due to the longitudinal current flowing in the primary. Capacitance will of course exist between the screen and windings 2-1, 6-5, but the balance of these windings is not, in general, critical, since in most cases any unbalances here will be swamped by the unbalances of following apparatus. On certain occasions, however, it may be desirable to have these windings balanced, and consideration is given in the design of such a transformer to achieve this as far as possible.

Careful manufacturing methods can produce a very good approximation to balance and such transformers enable quite large longitudinal currents to be harmlessly by-passed from the signal path.

Reverting to Fig. 5, consider the effect of introducing a 'repeating coil' between A'B' and the load L. $I_0$ will now cause no signal at the grid of the valve but $I_u$, the unwanted signal current, will be unaffected and will still develop a voltage at its grid. If we suppose that $I_u$ and $I_0$ are induced in the generator G, then the insertion of a repeating coil between it and AB will remove $I_0$ leaving $I_u$. Therefore, although the line transformer can be extremely effective in removing the deleterious effect of longitudinals, an unwanted circulating current will always cause an unwanted voltage at the load.

Let us now consider the passage of a longitudinal current along a pair of wires having relative variation in some primary constants. Fig. 7 shows a section PP'—NN' of a pair AA'—BB' with longitudinal current $I_0$ entering the section (and at PN the longitudinal voltage $= V_0$). The section having resistance $R + x$ from P — P' and $R$ from N—N' and leakance to earth from P' $= 1/R$ and from N' $= 1/(R' + x')$. Suppose $x = 0$, then voltage P' to earth and N' to earth $= V_0 - I_0R$.

Current to earth from P'

$$= \frac{V_0 - I_0R}{R}$$

and from N'

$$= \frac{V_0 - I_0R}{R' + x'}$$

Let current leaving section at P'

$$= I_p = I_0 - \frac{V_0 - I_0R}{R'}$$

Let current leaving section at N'

$$= I_m = I_0 - \frac{V_0 - I_0R}{R' + x'}$$

Therefore $I_m > I_p$

Hence the longitudinal current at this point

$$= \frac{I_m + I_p}{2}$$

There also exists due to $I_0$ a circulating current

$$I_c = \frac{I_m - I_p}{2}$$

Therefore due to unequal leakances the longitudinal current has produced a circulating current and, by a similar analysis, if $x$ is finite a similar result ensues. Hence, it will be seen that any irregularity of primary constants in a transmission pair will cause unwanted signal currents from any induced longitudinal. Thus, the capacitance and leakage to earth, also the wire resistance and inductance, ought to be identical for each wire along the length of the pair.

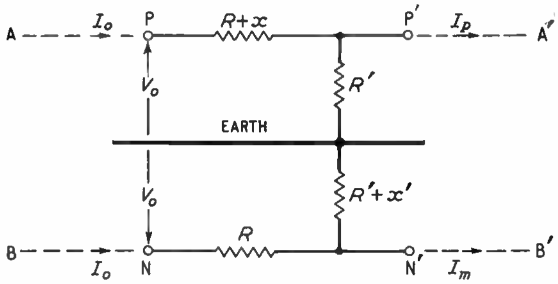


Fig. 7. *Conditions in a line in which the primary constants vary.*

Take the case where the transmission pair is one of many such made up as a cable. It was shown earlier that to reduce to a minimum the value of circulating currents magnetically induced, the wire-to-wire spacing should be small and the pair continuously transposed along its length. The second precaution is easy to realize, but the first, although desirable from the consideration of space, must not be carried so far as to make the wire-to-wire capacitance of the pair too great (about 0·07 $\mu$F/mile is about the maximum permissible for cable transmission of audio frequencies).

By care in manufacture all these requirements can be closely met in each section produced. The jointing of sections to produce one long cable must be done so as not to produce resistance unbalance in the pair at the joint, and it may be necessary to transpose the pairs of the section to maintain the best capacitive balance of a number of sections. It will also be seen that if the insulation of a cable breaks down, the wire-to-



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earth leakance of a pair may be seriously unbalanced. These unbalance conditions also have to be avoided at any other connection points in the overall circuit such as the 'jumpering' in a distribution frame, fuses, jacks, etc.

The remaining pairs of wire in a cable must be considered as potential inducers of unwanted signals in the pair under consideration. Fig. 8 shows a pair AB with an adjacent pair CD carrying a signal current $I_d$ and having capacitances $C_a$, $C_b$, as illustrated.

Let us assume $I_d$ to be small in magnitude (which will generally be the case), then due to this current in C and D being in opposite directions and the distance between wires C and D being small the magnetic field will be negligible and it will induce no appreciable current in A and B.

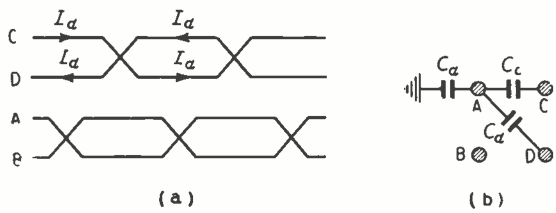


Fig. 8. *Two pairs of adjacent transposed wires (a) and the relevant capacitances (b).*

In Fig. 8 (b) is shown a section of AB and CD, let $V$ be voltage of C to earth and $-V$ be the voltage of D to earth due to a signal voltage of $2V$ between C and D and let A have a resultant voltage $V_a$ to earth.

$$V_a = V\frac{C_c}{C_a + C_c} - V\frac{C_d}{C_a + C_d}$$

Now if $C_c \neq C_d$, $V_a \neq 0$. Similarly, a voltage $V_b$ from B to C and D are not equal.

Hence it is essential in such a cable to ensure the best wire-to-wire capacitance balance for each pair between the pairs, and between each pair and the cable sheath (earth), as mentioned above. It will be obvious that one way of reducing the effects of unbalance capacitance coupling is to enclose each pair of wires in an electrostatic screen. This of course increases the bulk of the cable and also its cost. It further means that the pairs cannot be quadded. Screening, however, plays a valuable part in reducing induction in individual pairs of wires not part of a metallic sheathed cable—whose very sheath provides overall screening from outside sources of interference.

Let us consider the virtues of applying an earth to the individual screens in an individually-screened pair cable. The screens can only conveniently be earthed at the ends of the cable. It must be obvious that if there exists in a given pair a longitudinal current (with respect to earth) then, if there is a low resistance path to earth surrounding the pair, the current flowing through the capacitances between the screen and the pair will all return via the screen to the distant earth.

Such a current flowing in a conductor adjacent to other screens and pairs will magnetically induce unwanted currents in them. Therefore, in general, it is most inadvisable to make any earth connection to the screens of individual pairs.

In order to provide an output which is balanced with respect to earth, and isolated from it, it is usual to feed the output from a valve to its load via a transformer. Owing to practical design limitations, however, direct capacitance coupling between the primary and secondary windings of such a transformer cannot be completely eliminated. The result of this remanent coupling is the generation of longitudinal voltage in the output circuit.

In Fig. 9 let the direct capacitive coupling be represented as a lumped capacitance $C$ between the top and bottom ends of the windings as shown. (For simplicity they are shown as having equal values, if they were not it will be seen that then the unbalance will be accentuated.) Also, let $Z_1$ and $Z_2$ be the impedances to earth from 1 and 2.

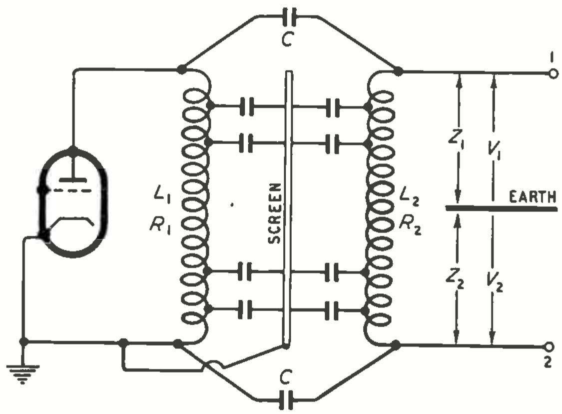


Fig. 9. *Illustrating direct capacitive coupling through a transformer.*

$Z_1$ = The parallel combination of $R_2 + j\omega L_2 + 1/j\omega C$ and $R_1 + j\omega L_1 + 1/j\omega C$

$Z_2 = 2/j\omega C$ (neglecting the high impedance path in parallel) see below.

(Where $R_1$ and $L_1$ are the resistance and shunt inductance of the primary, and $R_2$ and $L_2$ those of the secondary.)

In practice (for a 600-Ω output impedance)





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such a transformer will have $L_1$ and $R_1$ much greater than $L_2$ and $R_2$ thus

$$Z_1 = R_2 + j\omega L_2 + 1/j\omega C$$

and therefore $Z_1 > Z_2$. If the generated voltage appearing across 1 and 2 is $V$, the voltage between earth and 1 is $V_1$, and the voltage between earth and 2 is $V_2$

$$\text{Then } V_1 = \frac{-VZ_1}{Z_1 + Z_2}$$

$$\text{and } V_2 = \frac{VZ_2}{Z_1 + Z_2}$$

and as $Z_1 \neq Z_2$, $V_1 \neq -V_2$.

Hence, a longitudinal voltage exists at 1 and 2 with respect to earth.

The source of these voltages may be represented by a generator having an impedance $1/j\omega C$ (the real part of the impedance may be neglected) in series with a point on the transformer secondary and earth, and having a frequency equal to and a waveform related to that of the source of circulating current. The actual point on the winding is where the impedances to earth are both equal and are $(Z_1 + Z_2)/2$.

If $Z_1 = Z_2$ then there will of course be no longitudinal voltage induced due to unbalanced earth admittances. Longitudinal current may, however, be present due to another type of coupling; e.g., external. In these cases the disturbing generator may be represented as acting at the centre point of the winding.

In parenthesis, it will be seen that these longitudinal voltages exist despite the presence of the earthed electrostatic screen and, therefore, it might appear likely that similar conditions would apply to the repeating coil. This is in fact so, but to a much smaller degree because the direct winding to winding capacitance of a repeating coil is only of the order of 6% of that for an average input or output transformer (typically 15 pF instead of 250 pF.) This is achieved by having a transformer of approximately unity turns ratio, requiring an inductance that need only be large compared with the impedance of the apparatus connected to it—normally of the order of 600 Ω and therefore the limited number of turns required enables the most efficient use to be made of the available winding space to result in minimum inter-winding capacitance.

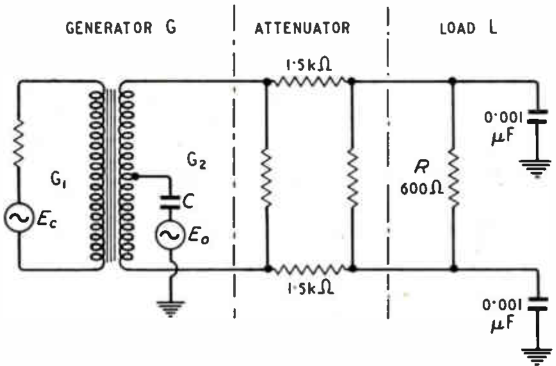


Fig. 10. *Behaviour of attenuator in presence of longitudinal current.*

Consider the apparatus illustrated in Fig. 10, where an attenuator having 20 dB loss is inserted between the generator G having a source of circulating e.m.f. $E_c$ which produces circulating voltage $V_c$ across the load resistor $R$, and a source of longitudinal e.m.f. $E_0$ connected through an impedance $1/j\omega C$. If the circulating source impedance is 600 Ω and equal to $R$ and the attenuator give 20 dB loss under these conditions, the total value of series resistance in the pad will be approximately 3,000 Ω.

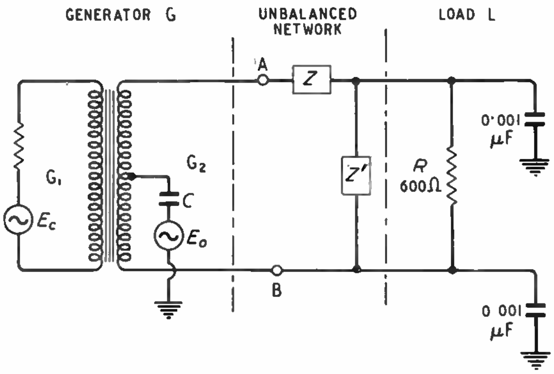


Fig. 11. *Behaviour of unbalanced network in presence of longitudinal current.*

Let us further suppose that the earth admittances at the load terminals are mainly capacitive (a typical value is of the order of 0·001 µF and the value of $C$ in the generator may be taken as 250 pF). Let us consider the behaviour of the attenuator in respect of the two types of current flowing through it. If the frequency of $G_1$ is 10 kc/s, then the frequency $G_2$ is also 10 kc/s. The impedance represented by $1/j\omega C$ is approximately 64,000 Ω, while the load to earth impedances are approximately 16,000 Ω. The attenuation of flow of the longitudinal current by introducing 1,500 Ω in an effective total path of 144,000 Ω is therefore negligible (less than 0·2 dB). The shunt arms of the attenuator, of course, introduce no loss at all to this current. It is obvious, therefore, that the 20-dB attenuator has increased the proportion of longitudinal to circulating voltage at the load terminals by nearly 20 dB or 10 times. At 1 kc/s the generator $G_2$ impedance and earth admittances are correspondingly increased and the effect more marked,



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in that the longitudinal loss is decreased; but, of course, the amount of this current will be considerably less.

Let us now consider Fig. 11 which shows an unbalance introduced in series with the generator G and load L of the previous example. Let the voltage developed across the load due to $G_1$ be $V$. As has been shown earlier, the presence of the unbalance will cause an unwanted circulating voltage $V_c$ at the load terminals due to any longitudinal voltage applied at points A and B. As the generator $G_2$ impedance is capacitive the amount of longitudinal current flowing through the unbalance will tend to increase with frequency and hence the unwanted voltage developed across the load will also tend to increase with frequency. As the generator $G_2$ will have a frequency identical to that of $G_1$ and a waveform related to that produced by $G_1$, it will be seen that $V_c$ may add or subtract from the wanted circulation voltage $V$ at the load terminals and, as voltage $V_c$ will vary with frequency, the effective insertion loss of the unbalance element introduced will not be that calculated by consideration of its loss to the circulating current, due to $G_1$ and this deviation is frequency dependent.

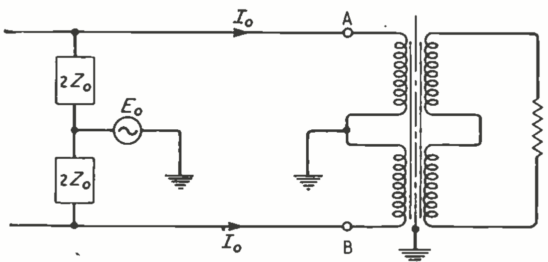


Fig. 12. *Effect of earthing centre tap of transformer at the receiving end.*

An example of such a connection is an amplifier feeding a transmission line followed by an equalizer terminated by an amplifier. There will be, in general, a longitudinal current due to imperfection in the sending-amplifier output transformer. This current will cause an unbalanced equalizer to have other than its designed result at the input to the receiver amplifier. Secondly, if in the transmission line a longitudinal current is induced from an external source, the equalizer unbalance will cause a 'noise' (or unwanted signal) voltage at the receiver amplifier output. It becomes necessary, therefore, to eliminate both these efforts by inserting a repeating coil immediately before the unbalanced equalizer.

The effects described when considering Fig. 10 show that the introduction of transmission loss following an output transformer considerably worsens its effective longitudinal output compared with the circulating voltage it is designed to deliver at the attenuated output. This use of a variable output attenuator is frequently resorted to in test oscillators and the above effect must be taken into account when using such apparatus.

Lastly, let us consider (Fig. 12) the receiving end of a transmission line terminated with a repeating coil, and the effect on longitudinal current due to applying an earth to the centre tap of the line winding on the transformer. Let $I_0$ be the longitudinal current flowing due to generator $E_0$. We have seen earlier that depending on whether $I_0$ is caused by electromagnetic or electrostatic induction the longitudinal generator approximates respectively a constant-voltage or constant-current generator.

In the first instance the connection of the centre tap will considerably lower the earth impedance from A and B, hence $I_0$ will increase and the greater part of it will flow through the windings.

If a constant-current generator is assumed, connection of the centre-tap earth will not increase $I_0$, but will increase that portion of it flowing through the windings. As this concept postulates $Z_0$ infinitely great with respect to all the other impedances in the return path this seldom occurs in practice, but it is useful to adhere to this concept when considering the earth-connected centre point.

If the current flowing through the line windings increases, then any resistive or inductance unbalance they may have will cause a larger induced voltage in the secondary windings.

In the case of electromagnetically-induced longitudinals the increase in $I_0$ due to the earth connection will cause a corresponding increase of unwanted circulating voltage at the load, due to any unbalances before it. The earth connection in this case will therefore considerably worsen the interference due to unbalance.

This fact provides a simple test for a practical circuit to determine how unwanted noise voltages are being induced. If the induction is electrostatic, the earth connection will not normally much increase the unwanted signal.

In general, therefore, it will be seen that it is not desirable to apply an earth connection to the centre tap of a repeating coil, used to terminate a transmission line.

For some other types of transformer which have fairly small but quite unbalanced winding to earth capacitances, the earth connection may improve the signal-to-noise ratio in the presence of longitudinals, but this necessitates reasonable inductive and resistive balance in the 'line winding' of such a transformer.



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# AMPLITUDE LIMITATION IN *LC*-OSCILLATORS

## *Using Two Biased Diodes*

**By Ziya Akçasu**

*(Assistant Professor at the Technical University of Istanbul, Turkey)*

**SUMMARY.**—An $LC$-oscillator which includes two biased diodes in the grid circuit to limit oscillation amplitude is analysed. Amplitude of oscillation and harmonic distortion are calculated and represented by curves. From these curves it is observed that oscillations can be modulated linearly; no frequency modulation occurs during amplitude modulation and harmonic distortion is very low. Also the circuit is found to be adequate for high frequency stability. The distinctive feature of the circuit is shown to be that the static conditions of the valve, such as bias voltage and direct anode current, are independent of the oscillation amplitude. A practical circuit is described.

### 1. Introduction

In general, an $LC$-oscillator is composed of an oscillation circuit which determines oscillation frequency and of a negative resistance which supplies energy to maintain oscillations. An oscillation circuit can be reduced to a parallel combination of an ideal inductance, a capacitance and a positive resistance which represents the total losses in the real circuit. Maintained oscillations occur when the energy supplied by the negative resistance becomes equal to that absorbed in the positive one. Oscillation amplitude is limited, therefore, by the non-linearity of either of these resistances[2]. Thermistors[5] (negative temperature-coefficient resistors) and Varistors[8] (voltage-dependent resistors) are the well-known non-linear positive resistances. They can be connected in parallel with the oscillation circuit to limit oscillation amplitude[4].

A negative resistance is usually obtained by means of a valve operated as a positive feedback amplifier. Hence, the non-linearity of a negative resistance may be due either to the non-linearity of the valve characteristic or to the non-linearity of the feedback circuit. An example of the former case is the conventional $LC$-oscillator, where the oscillation amplitude is limited by the non-linearity of the valve characteristic; the valve is operated in these oscillators as a class C power amplifier[9]. The latter case, where the non-linearity is due to the feedback circuit, is the subject of this paper and will be dealt with in detail.

### 2. Description of the Circuit

Fig. 1 shows the block diagram of the oscillator circuit; it consists of a tuned amplifier and a positive feedback circuit. The amplifier comprises a valve which is operated in class A. The valve characteristics are assumed to be linear. This property of the circuit is one of its distinctive features.

Feedback is obtained through an attenuator which provides the coupling and the proper phase shift. The attenuator is followed by two biased diodes*. When the output voltage of the attenuator is below the bias voltage $E$, the diodes are not conducting and hence the attenuator is terminated by the non-conducting resistances of the diodes; the attenuation factor of the attenuator is then denoted by $\beta$. If, on the other hand, the bias voltage is exceeded the diodes become conducting and, since their conducting resistance is assumed to be negligible, the output voltage remains equal to the bias voltage $E$. Hence a clipped waveform is obtained. The ratio of the fundamental component of this wave to that of the input voltage is defined as the attenuation factor. It will be shown below that the attenuation factor in this new situation depends upon the magnitude of input voltage. Thus, one obtains a non-linear feedback. It is important to note that the diodes are not operated as rectifier elements producing a negative bias to control oscillation

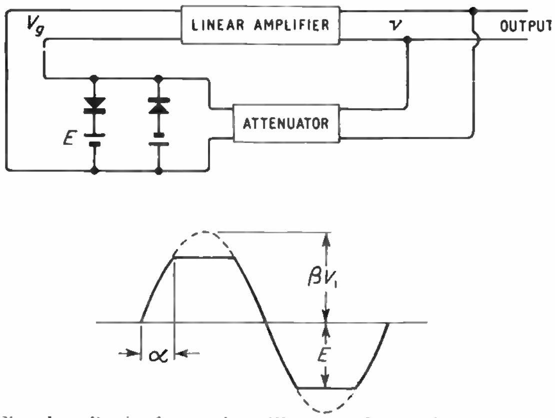


Fig. 1. *Basic form of oscillator and waveform clipped at the level E by the diodes.*

MS accepted by the Editor, June 1955

* See Appendix.



C

amplitude. This point is also one of its distinctive features[7]†.

It is now assumed that the input impedance of the attenuator is so much greater than the output impedance of the amplifier that the former can be neglected since they are in parallel. This assumption is made in order to prevent the non-linear feedback circuit impairing the linearity of the amplifier.

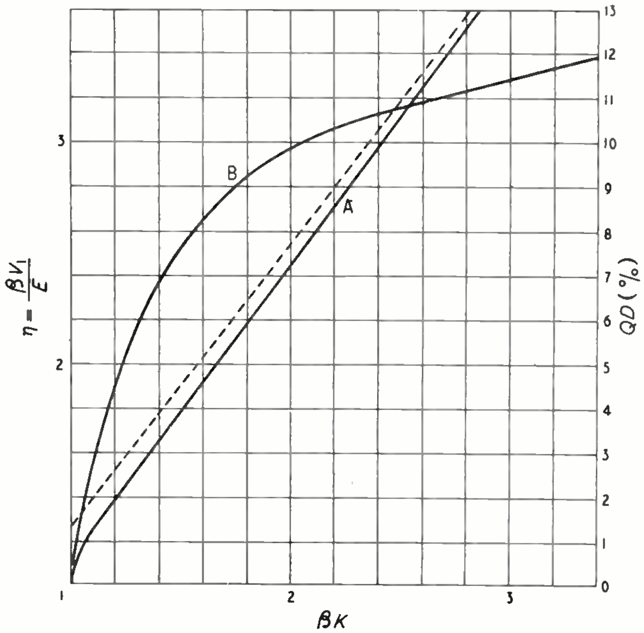


Fig. 2. *Relation between loop gain $\beta K$ and clipping level (curve A) and product of distortion and Q (curve B).*

### 3. Amplitude of Oscillation

It will be shown below that the output voltage $v$ of the oscillator contains only odd harmonics and its Fourier expansion is of the form:

$$v = V_1 \sin \omega t + V_3 \sin 3\omega t + \ldots \quad \ldots \quad (1)$$

As a first approximation, the effect of harmonics on the amplitude will be neglected. This is equivalent to assuming that the voltage applied to the diodes is a pure sine wave and is equal to $\beta V_1 \sin \omega t$ (Fig. 1). This assumption makes it possible to express the clipped sine wave at the grid as a simple Fourier series. When the voltage applied to the diodes is an arbitrary periodic function of time, the output voltage will be again composed of only odd sine harmonics; but the expressions giving the amplitudes of harmonics will now involve Bessel functions[3]. Hence the calculations are very long even if only the third harmonic is taken into account.

† See Ref. 9, p. 205.

The Fourier expansion of a clipped sine wave, as shown in Fig. 1, is known to be

$$v_g = B_1 \sin \omega t + B_3 \sin 3\omega t + \ldots \quad \ldots \quad (2)$$

where

$$B_1 = \frac{2}{\pi}\beta V_1(\alpha + \frac{1}{2}\sin 2\alpha) \quad \ldots \quad \ldots \quad (3)$$

$$B_3 = \frac{1}{3\pi}\beta V_1(\sin 2\alpha + \frac{1}{2}\sin 4\alpha) \ldots \quad \ldots \quad (4)$$

In these expressions $\alpha$ is the angle shown in Fig. 1 and defined as

$$\sin \alpha = \frac{E}{\beta V_1} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

This expansion holds as long as $\alpha < \pi/2$; i.e., $\beta V_1 > E$. When $\beta V_1 < E$, the diodes are not conducting and hence the oscillator circuit is linear. In linear circuits the condition of self-excitation is known to be

$$\beta K \geqslant 1$$

where $K$ denotes the gain of the amplifier at the resonant frequency. If the above condition is satisfied, oscillations start spontaneously and the oscillation amplitude increases exponentially until the instantaneous value of the voltage applied to the diodes reaches the bias voltage. From now on the voltage peaks are clipped and the circuit becomes non-linear. Thus, harmonics are produced and expansion (2) holds.

When the steady state is reached the following relation holds between the fundamental components of the input and output voltages of the amplifier:

$$B_1 K = V_1 \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

By substituting $B_1$ from Equ. (3) one obtains

$$\frac{2}{\pi}(\alpha + \frac{1}{2}\sin 2\alpha) = \frac{1}{\beta K} \quad \ldots \quad \ldots \quad (7)$$

If the attenuation $\beta$ and the gain $K$ are given, $\alpha$ can be obtained from this equation; oscillation amplitude $V_1$ is then calculated from Equ. (5). The curve A in Fig. 2 shows the relation between $\beta K$ and $\eta$ where

$$\eta = \frac{V_1 . \beta}{E} \quad \ldots \quad \ldots \quad \ldots \quad (8)$$

The curve approaches asymptotically the dotted straight line $\eta = \frac{4}{\pi}(\beta K)$.

From the graph one can draw the following conclusions:

(a) If the attenuation $\beta$ and the bias voltage $E$ are kept constant, oscillation amplitude increases with the gain of the amplifier, being roughly proportional to it.



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(b) Since for a given value of $\beta K$, $\eta$ has a certain value, the amplitude of the oscillation $V_1$ is proportional to the bias voltage $E$. Therefore, the control of the bias voltage of the diodes enables the oscillation amplitude to be varied within wide limits. In an actual circuit the extent of the linear portion of the valve characteristic sets an upper limit to the oscillation amplitude.

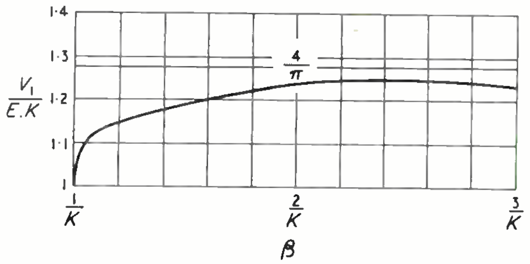


Fig. 3. *Variation of amplitude of oscillation with attenuation.*

It also follows that the oscillation can be modulated by superposing an audio-frequency voltage upon the bias voltage $E$. Since the amplitude is exactly proportional to the bias voltage, the modulation characteristic will be linear, provided the operation remains in the linear part of the valve characteristic. The depth of modulation can be increased up to 100%. As is shown below, no frequency drift is present during this modulation.

In class C *LC*-oscillators, however, the oscillation is modulated by varying the anode supply voltage but, when the anode voltage falls to very low values during modulation, the valve ceases to oscillate, which sets a limit for the depth of modulation. Besides this, the modulation characteristic is not linear in such oscillators and frequency drift occurs during modulation.

(c) When the gain $K$ and the bias voltage $E$ are held constant, the oscillation amplitude varies with the attenuation $\beta$ as shown in Fig. 3. It is observed from the curve that for $\beta = 1/K$ (i.e., when the oscillation just starts) the oscillation amplitude is equal to $EK$. For higher values of $\beta$ the curve first increases rapidly, then reaches a very flat maximum and falls slightly. For still higher value of $\beta$ the curve approaches asymptotically to $4/\pi = 1{\cdot}27$; this part of the curve is not shown in the figure. It follows that the magnitude of feedback denoted by $\beta$ has not much effect on the oscillation amplitude, but the values of $\beta$ corresponding to the flat part of the curve are advisable since, on this part of the curve, any small variation of $\beta$ causes a relatively smaller change in amplitude. It will be shown in what follows that the harmonic distortion increases with $\beta$, and suitable values of $\beta$ are between $1{\cdot}1/K$ and $1{\cdot}3/K$.

## 4. Harmonic Distortion

Fourier expansion of the grid voltage given in Equ. (2) shows that the magnitude of the harmonics decreases rapidly with increasing harmonic number. Moreover, the gain of the tuned amplifier falls steeply for the higher harmonics, and only the third harmonic need be considered in the calculation of harmonic distortion.

The impedance of the tuned circuit for the third harmonic is

$$|Z_3| = \frac{3}{8}\omega L \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

where $L$ is the inductance of the tuned circuit. If $g_m$ denotes the mutual conductance of the valve, the gain of the amplifier for the third harmonic is

$$K_3 = \frac{3}{8}\omega L g_m \quad \ldots \quad \ldots \quad \ldots \quad (10)$$

where the anode resistance of the valve is assumed to be much greater than the impedance of the tuned circuit. Since, for reasons which will be mentioned later, screen-grid valves are preferred for this oscillator circuit, this assumption is justified.

By remembering $K = \omega L Q g_m$ one can transform Equ. (10) into the form

$$K_3 = \frac{3}{8} \cdot \frac{K}{Q} \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

where $Q$ is the $Q$-factor of the tuned circuit.

The amplitude of the third harmonic at the grid is given in Equ. (4). By multiplying this by $K_3$ one obtains the amplitude $V_3$ of third-harmonic at the anode. Dividing by $V_1$ gives the harmonic distortion, i.e.,

$$D = \frac{V_3}{V_1} = \frac{1}{8\pi}\frac{\beta K}{Q}\left(\sin 2\alpha + \frac{1}{2}\sin 4\alpha\right) \quad \ldots \quad (12)$$

where $\alpha$ should be substituted from Equ. (7). By combining Equs. (7) and (12) one can see that the product $DQ$ depends solely upon $\beta K$. The curve $B$ in Fig. 2 represents the relationship between $DQ$ and $\beta K$. The curve approaches asymptotically to the value of $0{\cdot}125$ for the higher values of $\beta K$.

Equ. (12) and the curve show that:—

(a) Harmonic distortion is inversely proportional to the $Q$-factor of the tuned circuit. A high $Q$-factor is essential therefore for low harmonic distortion. One of the causes which reduce the effective $Q$-factor of the tuned circuit in an oscillator is the internal resistance of the valve. Besides the reasons which will be mentioned later, screen-grid valves are preferable to others because



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they have a high anode resistance. Alternatively, current feedback can be used to increase the internal resistance, which also serves to improve the linearity of the valve characteristic.

(b) Harmonic distortion increases with the product $\beta K$ and it has been shown previously that a suitable value of $\beta K$ is 1·2. The harmonic distortion corresponding to this value is found from the curve to be $(4{\cdot}6/Q)\%$ which approximately gives 0·1% for a tuned circuit having $Q = 50$. This shows that the harmonic distortion can be easily decreased to very low values.

(c) The harmonic distortion is independent of the oscillation amplitude. This point will be returned to later.

## 5. Frequency of Oscillation

The well-known interdependence between the frequency of self-maintained oscillations and the harmonic content is expressed mathematically as follows[1,2,*]

$$\frac{\Delta\omega}{\omega_0} = -\frac{1}{2}\left[3\left(\frac{V_2}{V_1}\right)^2 + 8\left(\frac{V_3}{V_1}\right)^2 + 15\left(\frac{V_4}{V_1}\right)^2 + ..\right] \quad .. \quad (13)$$

where $\omega_0$ is the natural frequency of the tuned circuit and where $\Delta\omega = \omega - \omega_0$. If only the third harmonic is considered, this equation takes the form

$$\frac{\Delta\omega}{\omega_0} = -4D^2 \quad .. \quad .. \quad .. \quad (14)$$

This suggests that a harmonic distortion of 0·1% gives a frequency reduction of about four parts in a million.

The fact that harmonic distortion is independent of oscillation amplitude together with Equ. (14), shows that frequency reduction is also independent of oscillation amplitude. Hence, it follows that amplitude variations due to amplitude modulation do not give rise to any frequency drift. This point has been previously referred to.

In a class C oscillator, however, amplitude modulation is always accompanied by some degree of frequency modulation. This can be seen by considering the kind of amplitude limitation in these oscillators. The rectification at the grid produces a negative bias which makes the operating point more negative when oscillation amplitude increases. Thus, the character of the non-linearity of the valve and, consequently the harmonic content, change with the oscillation amplitude. This explains why frequency modulation occurs during amplitude modulation. Variations of anode voltage due to modulation also cause the operating point to shift. The above argument is also true for the circuit given in Ref. 7 where an external diode is used to produce the negative bias voltage.

It has been found that the frequency variation due to change in interelectrode capacitance with variation of operating conditions of the valve is of far more significance than effects due to the harmonic content[9]. The capacitance between any two electrodes in a valve is dependent on the space charge as well as on their geometrical disposition. Therefore it varies with the voltage applied to the electrodes and the mean anode current. Since the valve in the described oscillator is operated in class A and its characteristics are assumed to be linear, the mean anode current does not vary with the oscillation amplitude, and it follows that the capacitance introduced in the tuned circuit is independent of the oscillation amplitude; consequently, no frequency modulation is present during amplitude modulation.

This argument shows that a valve having a small anode–earth capacitance should be preferred; this is one of the reasons for using a pentode for the oscillator circuit discussed in this paper.

In pentodes, the variation of the direct current with change of anode-supply voltage is small; the same is also true for the mutual conductance of a pentode. If the valve is automatically biased by a cathode resistor, this variation is still smaller, because any variation in anode voltage is accompanied by an opposite change in the grid voltage. Hence, the variations of anode voltage have little effect on the frequency stability of the oscillator.

Variation of the screen-grid voltage is more significant than that of the anode voltage, therefore it is sufficient to stabilize only this voltage.

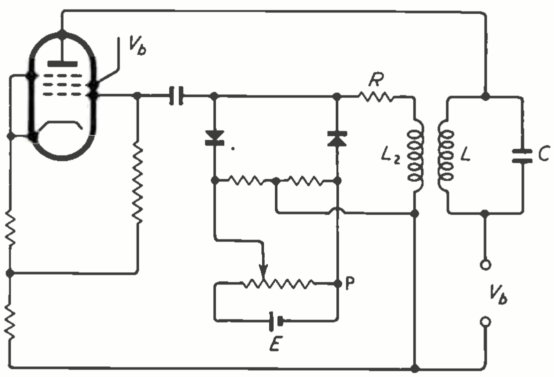


Fig. 4. *Circuit employed for experimental work.*

## 6. Application

The circuit used by the author for the experiments is shown in Fig. 4. Germanium crystals were used as diodes. The potential divider P enables the bias voltages on the two diodes to be

*See also Ref. 9, p. 70.



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varied simultaneously. The resistor $R$ is inserted in series with $L_2$ in order to prevent the diodes short-circuiting the coil $L_2$. This ensures that the tuned circuit is not damped by the feedback circuit. The parts played by the other elements in the circuit are self-explanatory.

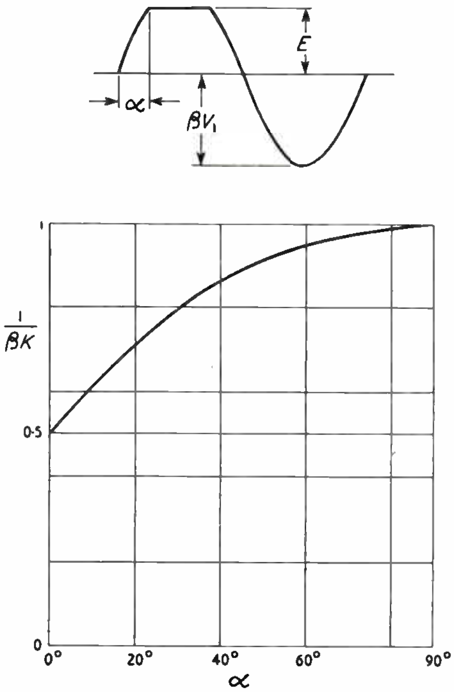


Fig. 5. *Conditions for a single diode clipper.*

## 7. Conclusion

The use of diodes as the non-linear element makes it possible to operate the valve in class A and also to assume its characteristics to be linear. The distinctive feature of the circuit lies in the fact that diodes are not used to produce a negative bias by rectifying the oscillations; they simply produce a clipped wave whose fundamental is not proportional to that of the voltage applied to them. Since the operating conditions of the valve do not change with the oscillation amplitude, the circuit has a high stability of frequency with a linear amplitude modulation, without any frequency drift and finally produces oscillations with a very low harmonic content.

## APPENDIX

If only one diode is used at the grid, amplitude limitation is not always possible; beyond a certain value of coupling, oscillation amplitude is not under control and increases indefinitely. To show this one can follow the same procedure as that used in the case of double diodes. The clipped sine wave in this case has the form shown in Fig. 5 and its Fourier expansion is as follows:

$$v_g = B_1 \sin \omega t + B_3 \sin 3\omega t + \ldots$$
$$+ A_0 + A_2 \cos 2\omega t + \ldots$$

The fundamental component $B_1$ is

$$B_1 = \frac{1}{\pi}\left(\alpha + \frac{1}{2}\sin 2\alpha + \frac{\pi}{2}\right)V_1 . \beta$$

The equation for determining oscillation amplitude can be found as in the case of two diodes; viz.:

$$\frac{1}{\beta K} = \frac{1}{\pi}\left(\alpha + \frac{1}{2}\sin 2\alpha + \frac{\pi}{2}\right)$$

$$\sin \alpha = \frac{E}{V_1 . \beta}$$

The curve shown in Fig. 5 represents the relationship between $\beta K$ and $\alpha$. It is observed from this curve that the amplitude of oscillation has a finite value if $\beta K$ has values satisfying

$$1 < \beta K < 2$$

As $\beta K$ approaches 2, oscillation amplitude increases indefinitely. For values of $\beta K$ larger than 2, oscillations are unlimited and never reach any steady state; the amplitude is not under control and is independent of the bias voltage $E$.

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# NEW BOOKS

**Ondes Centimétriques: Lignes-Circuits-Antennes**

By G. Goudet and P. Chavance. Pp. 422 with 263 illustrations. Chiron, 40 rue de Seine, Paris 6. Price Fr. 5200 (postage, Fr. 100).

The authors are professors at the École Nationale Supérieure, but at present the former is Director of the Laboratoire Central des Télécommunications, while the latter is head of the "Câbles Hertziens" Department of the French Thomson-Houston Co. The book has been specially written for those students who, having obtained a general knowledge of radiotelegraphy, wish to concentrate on the three branches of the subject indicated in the title. It is therefore divided into three parts, the first of which, after an introductory review of the fundamental laws of electromagnetism, has a chapter on the $TE_{01}$ wave of the rectangular guide, followed by a chapter entitled "a general study of guided waves". The second part entitled "circuits" consists of four chapters dealing with dipoles, quadripoles, multipoles, and cavities. The third part entitled "aerials" is divided into two chapters, the first on the general properties of aerials, and the second on the principal types of aerial, with an appendix on Babinet's Principle. The references given at the end of each chapter are divided into general works and particular references, a résumé of the former being also given at the end of the book, together with an index and a very comprehensive table of contents.

Each chapter concludes with a number of exercises, each marked with a symbol to indicate whether it is regarded as easy, or of medium difficulty, or difficult. The preface concludes with a tribute to Maxwell "from whose celebrated equations written in 1867 all this work flows". As the authors say in the preface, the subjects dealt with in the book are no longer of interest only to specialists in radar and telecommunications, since the same techniques have penetrated into the field of nuclear energy and the particle accelerator and into other fields. The book will undoubtedly prove valuable to those with the necessary fundamental knowledge who wish to master the intricacies of waveguides and the various elements of short-wave circuits and aerials.

The names of English and German books in the bibliography have not been carefully checked. We have noted Microwave Cricuits, Principales of Microcrowave Circuits, and Ausgewhälte Fragen, but these are minor details compared with the general excellence of the book.

G.W.O.H.

**Mathematische Methoden in der Hochfrequenztechnik**

By Klaus Pöschl. Pp. 331 + viii with 165 illustrations. Springer-Verlag, Reichpietschufer 20, Berlin, W.35. Price Dm. 36.

Dr. Pöschl is in the development department of the Siemens and Halske valve works in Munich, and this book is the outcome of the desire to have at hand in a single volume the mathematical material which is essential to the solution of the theoretical problems of high-frequency research and development. The book is intended both for the practising engineer or physicist and for the student, and can be regarded either as a textbook or as a book of reference.

The author regards it as made up of two parts: the first ten chapters develop the mathematics and the last five deal with its application to field problems, cavity resonators, waveguides, aerials, magnetrons, waves in space-charges, etc. The early chapters deal with scalar and vector fields, determinants and matrices, complex quantities and circle diagrams, and analytical multi-valued functions, conformal representation, Fourier series and integrals, Laplace transformation, statistics, linear differential equations of the second order, cylindrical and spherical functions, methods of approximate solution using step by step methods. This selection of a few headings will give an idea of the wide ground covered.

The material has been very carefully prepared and arranged: a slip giving eleven errata is inserted in the book, but unfortunately one of the corrections is in need of further correction. In addition to the table of contents, there are extensive lists of references both to books and to papers on the subject, which, it should be emphasized, is not high-frequency engineering but the application of mathematics in the problems that arise.

G.W.O.H.

**CORRECTION**

We have been requested to point out that in the Rola Celestion advertisement (April issue) the size of the pole piece was incorrectly given as 1/5th″. This should, of course, have read 1·5″.

**STANDARD-FREQUENCY TRANSMISSIONS**

(Communication from the National Physical Laboratory)

*Values for April 1956*

| Date 1956 April | Frequency deviation from nominal: parts in $10^8$ | |
|---|---|---|
| | MSF 60 kc/s 1429-1530 G.M.T. | Droitwich 200 kc/s 1030 G.M.T. |
| 1 | +0·4 | N.M. |
| 2 | +0·4 | 0 |
| 3 | +0·4 | −3 |
| 4 | +0·4 | +1 |
| 5 | +0·4 | −3 |
| 6 | +0·3 | +2 |
| 7 | +0·4 | −2 |
| 8 | +0·4 | −3 |
| 9 | +0·4 | −3 |
| 10 | +0·3 | −3 |
| 11 | +0·4 | −3 |
| 12 | +0·4 | −3 |
| 13 | +0·4 | −2 |
| 14 | N.M. | −3 |
| 15 | N.M. | +2 |
| 16 | +0.4 | 0 |
| 17 | +0·5 | 0 |
| 18 | +0·5 | N.M. |
| 19 | +0·4 | 0 |
| 20 | +0·4 | +2 |
| 21 | +0·4 | 0 |
| 22 | +0·4 | −2 |
| 23 | +0·5 | −2 |
| 24 | +0·5 | −2 |
| 25 | +0·5 | −2 |
| 26 | +0·5 | 0 |
| 27 | +0·6 | −1 |
| 28 | N.M. | −1 |
| 29 | N.M. | 0 |
| 30 | +0·6 | +4 |

The values are based on astronomical data available on 1st May 1956.
N.M. = Not Measured.



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# 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.*



## ACOUSTICS AND AUDIO FREQUENCIES

534.213 1601

**The Transmission of a Plane** [acoustic] **Wave between Parallel Plates.**—I. D. Campbell. (*Acustica*, 1955, Vol. 5, No. 6, pp. 298–302.) Analysis is presented taking account of viscosity and thermal conduction. An approximate method is used which allows the attenuation and phase velocity to be deduced for all frequencies. Results are compared with measured values.

534.232-14-8: 534.133 1602

**The Performance of a Quartz Oscillator in Liquids.**—S. Parthasarathy & V. Narasimhan. (*Z. Phys.*, 12th Dec. 1955 & 10th Jan. 1956, Vol. 143, Nos. 3 & 5, pp. 300–311 & 623–631. In English.) The ultrasonic output was determined by a calorimetric method. The efficiency of conversion was investigated in various liquids at frequencies of 2·8, 4·9, 8·7 and 14·7 Mc/s.

534.6-8 1603

**A Reverberation Method for the Measurement of the Absorption of Ultrasonics in Liquids.**—L. E. Lawley & R. D. C. Reed. (*Acustica*, 1955, Vol. 5, No. 6, pp. 316–322.)

534.79 1604

**Loudness of Steady Noises.**—E. Zwicker & R. Feldtkeller. (*Acustica*, 1955, Vol. 5, No. 6, pp. 303–316. In German.) A method of determining the loudness of sustained noises is described based on subjectively derived equal-loudness contours, the measured bandwidth of the frequency groups into which the ear analyses the noise, and the mutual reduction effect of the adjacent groups.

534.846.4 1605

**Sound Amplification in Reverberant Spaces.**—A. F. B. Nickson. (*Aust. J. appl. Sci.*, Dec. 1955, Vol. 6, No. 4, pp. 476–485.) A system of vertical columns of loudspeakers, as proposed by Parkin & Taylor (1506 of 1952), is considered best. Three practical cases of improvements thus effected are described, and curves are given showing correct dimensions and positioning of columns for halls of various lengths.

534.86: 621.375.2.029.3 1606

**Phase Shift and Sound Quality.**—J. Moir. (*Wireless World*, April 1956, Vol. 62, No. 4, pp. 165–168.) Experiments on the toleration of phase shifts in a.f. amplifiers are reported. Results indicate that phase shifts introduced by typical domestic amplifiers are of little practical importance.

621.395.612.4 1607

**The Design of a Ribbon-Type Pressure-Gradient Microphone for Broadcast Transmission.**—D. E. L. Shorter & H. D. Harwood. (*B.B.C. Engng Div. Monographs*, Dec. 1955, No. 4, pp. 1–22.) Detailed account of development work leading to the production of microphone Type PGS, with reduced size and weight and improved response.

621.395.623.5 1608

**The Natural Frequencies of Horns.**—T. Lange. (*Acustica*, 1955, Vol. 5, No. 6, pp. 323–330. In German.) Calculations and measurements have been made of the input impedance of a system comprising a pressure chamber, a cylindrical connection, and a hyperbolic or catenoidal horn. In the general case the combined effects of the pressure chamber and the horn shape produce inharmonic resonances, but the two effects can be balanced to produce harmonic resonances.

621.395.625.3: 534.76 1609

**Design of Magnetic Recording and Reproducing Equipment for Domestic Use with Special Reference to Stereophonic Reproduction.**—M. B. Martin & D. L. A. Smith. (*J. Brit. Instn Radio Engrs*, Feb. 1956, Vol. 16, No. 2, pp. 65–77. Discussion, pp. 77–79.)



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681.84:534.851 **1610**

**Sapphire and Diamond Needles for reproducing Gramophone Disks.**—P. H. Werner. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, 1st Dec. 1955, Vol. 33, No. 12, pp. 504–511. In French.) Tests are reported to determine the playing time of both sapphire and diamond needles before quality of reproduction deteriorates noticeably. Photographs of unused and used needles are reproduced. The higher cost of the diamond needles is out of proportion to their longer service except for professional users. Where diamond needles are used, special precautions must be taken in respect of their finish.

## AERIALS AND TRANSMISSION LINES

621.372.029.6 **1611**

**Symposium on Microwave Strip Circuits.**—(*Trans. Inst. Radio Engrs*, March 1955, Vol. MTT-3, No. 2, pp. 1–177.) The text is given of 22 papers presented at a symposium held in October 1954; strip-line, microstrip and tri-plate lines and components using them are described. Abstracts of all the papers are given in *Proc. Inst. Radio Engrs*, July 1955, Vol. 43, No. 7, pp. 894–895.

621.372.2: 621.385.029.6 **1612**

**Coupled Helices.**—J. S. Cook, R. Kompfner & C. F. Quate. (*Bell Syst. tech. J.*, Jan. 1956, Vol. 35, No. 1, pp. 127–178.) An analysis of coupled helices is presented, based on transmission-line and field theory. Applications based on the presence of one and of both normal modes of propagation are described, and curves and equations useful in the design of travelling-wave valves and other microwave equipment are presented.

621.372.2.012 **1613**

**New Diagram for solving Impedance Transformations.**—R. Guillien. (*Onde élect.*, Dec. 1955, Vol. 35, No. 345, pp. 1164–1170.) If the reflection coefficient of a transmission line is represented by its logarithm, the standard Smith chart may be replaced by a logarithmic chart of orthogonal curves on which impedance transformations may be effected by simple translation, avoiding the rotations required on the Smith chart.

621.372.22: 621.372.51 **1614**

**Nonuniform Transmission Lines as Impedance Transformers.**—J. Willis & N. K. Sinha. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 166–172.) "The equation for the reflection coefficient at one end of a nonuniform transmission line matched at the other end is considered, and an approximate form of solution is suggested which enables such lines to be designed for optimum performance as matching sections. A number of examples are calculated, and the results are compared with lines previously described in literature." See also 664 of March.

621.372.8: 621.318.134 **1615**

**Energy Concentration Effects in Ferrite-Loaded Waveguides.**—J. L. Melchor, W. P. Ayres & P. H. Vartanian. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 72–77.) The influence of geometric factors on the microwave transmission characteristics for the two circularly polarized waves in a circular waveguide with an axially mounted ferrite rod are studied. The results support the prediction by Fox & Weiss (*Rev. mod. Phys.*, Jan. 1953, Vol. 25, No. 1, pp. 262–263), made in a comment on a paper by Hogan (*ibid.*, pp. 253–262), that the energy concentration within the ferrite is greater for one of the circularly polarized waves than for the other.

621.396.67 **1616**

**Folded Unipole Antennas.**—J. Leonhard, R. D. Mattuck & A. J. Poté. (*Trans. Inst. Radio Engrs*, July 1955, Vol. AP-3, No. 3, pp. 111–116.) Analysis for folded unipoles less than $\lambda/4$ in length as input impedance transformers is presented and verified by experiment. Practical applications are proposed.

621.396.67 **1617**

**A New Interpretation of the Integral-Equation Formulation of Cylindrical Antennas.**—C. T. Tai. (*Trans. Inst. Radio Engrs*, July 1955, Vol. AP-3, No. 3, pp. 125–127.) The conventional solution, based on an approximate integral equation, is verified by a method using the exact equation for a cylindrical shell; the new method is applicable to relatively thick aerials.

621.396.67: 621.315.62 **1618**

**A New Type of Aerial Insulator for High Voltages and Tensile Stresses.**—W. Peters. (*Nachrichtentech. Z.*, Dec. 1955, Vol. 8, No. 12, pp. 632–635.) An insulator for use in stays of mast aerials is described; the optimum distribution of the insulators along the stays is indicated.

621.396.67: 621.396.969 **1619**

**Reflection of Electromagnetic Waves from Thin Metal Strips (Passive Antennae).**—Lindroth. (See 1731.)

621.396.677.3 **1620**

**Use of Folded Monopoles in Antenna Arrays.**—J. B. Lewis. (*Trans. Inst. Radio Engrs*, July 1955, Vol. AP-3, No. 3, pp. 122–124.) "A method of calculating the driving point impedances from the self and mutual impedances of related unfolded elements is given."

621.396.677.45 **1621**

**Ground-to-Air Antenna uses Helical Array.**—V. J. Zanella. (*Electronics*, March 1956, Vol. 29, No. 3, pp. 161–163.) An u.h.f. aerial producing vertical polarization and consisting of a multi-element appropriately phased helical array gave a beam width at half-power points of 20° in the vertical plane and 45° in the horizontal plane. Constructional features for keeping the wind loading low are described.

621.396.677.51: 621.318.134: 621.396.93 **1622**

**Ferrite Aerials for Goniometer Direction Finders.**—G. Ziehm. (*Telefunken Ztg*, Dec. 1955, Vol. 28, No. 110, pp. 227–234. English summary, p. 265.) A discussion of the design of d.f. aerials for aircraft. The numerical calculations refer to a frequency of 300 kc/s and a magnetic field strength of 0·15 A/m. Arrangements of parallel rods offer advantages.

621.396.677.71 **1623**

**The Radiation Field produced by a Slot in a Large Circular Cylinder.**—L. L. Bailin. (*Trans. Inst. Radio Engrs*, July 1955, Vol. AP-3, No. 3, pp. 128–137.) The results obtained by Silver & Saunders (1588 of 1950) are used in the computation of tables giving the magnitude and phase of the principal component of the far-zone electric field for $\lambda/2$ slots.

621.396.677.81.012.12 **1624**

**Radiation of Electric Vibrators located near an Ideally Conducting Elliptic Cylinder.**—G. N. Kocherzhevski. (*Zh. tekh. Fiz.*, June 1955, Vol. 25, No. 6, pp. 1140–1154.) Polar diagrams of the vibrators are calculated by determining the total field as a sum of the fields of incident (plane) and diffracted waves and then



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applying the principle of reciprocity. The cases of longitudinal, transverse and radial vibrators are considered separately and a study is made of the effects of the shape and size of the cylinder and of the position of the vibrator. A comparison is made between the theoretical and experimental polar diagrams; under certain conditions good agreement is obtained.

621.396.677.833 **1625**

**Effect of Arbitrary Phase Errors on the Gain and Beam-Width Characteristics of Radiation Pattern.**—D. K. Cheng. (*Trans. Inst. Radio Engrs*, July 1955, Vol. AP-3, No. 3, pp. 145–147.) Expressions applicable to microwave parabolic reflectors are derived giving the maximum reduction of gain and the maximum change in main-lobe beam-width when the peak value of the aperture phase deviation and the amplitude distribution function are known.

621.396.677.833 **1626**

**Design and Construction of Double-Curvature Reflectors.**—L. Thourel. (*Onde élect.*, Dec. 1955, Vol. 35, No. 345, pp. 1153–1163.) A practical method for calculating the contours of a surface with given reflecting properties is presented and the effect on the radiation pattern of varying the position of the primary source is examined. Diffraction is taken into account. Calculated patterns agree with experimental results.

621.396.677.833.1 **1627**

**Parabolic Cylinder Aerials.**—K. Foster. (*Wireless Engr*, March 1956, Vol. 33, No. 3, pp. 59–65.) For cm-$\lambda$ aerials the ratios of whose beam-widths in two orthogonal planes are greater than about 8 : 1, parabolic cylinders are more practicable than paraboloidal reflectors. The radiation pattern of the parabolic cylinder is studied theoretically and design criteria are established. Comparison with performance figures given by Kiely (1572 of 1951) indicates that the theory is accurate enough for practical purposes.

621.396.677.85: 537.226 **1628**

**Study of the Diffraction of Electromagnetic Waves by an Array of Perforated Plates.**—G. Broussaud. (*Ann. Radioélect.*, Jan. 1955, Vol. 10, No. 39, pp. 42–63.) Artificial dielectrics comprising stacked metal plates with holes arranged in regular lines are investigated. The phenomena involved are conveniently represented as a series of guided propagations. With oblique incidence, the coupling between the individual guides provides an explanation of the refraction process. The critical angle at which incident energy is entirely absorbed is related simply to the hole spacing. Application of the results to the design of microwave lenses is indicated.

## AUTOMATIC COMPUTERS

681.142 **1629**

**Electronic Computers.**—(*Elektronische Rundschau*, Oct. 1955, Vol. 9, No. 10.) The main part of this issue is devoted to a series of papers on digital computers, with titles as follows:—

Programme-Controlled Computers.—H. J. Dreyer (pp. 341–343).

From the Punched-Card Computer to the EDPM [electronic data-processing machine].—O. Schröter (pp. 344–348).

Micro-program Control Mechanism.—H. Billing & W. Hopmann (pp. 349–353).

The Parallel Adding Mechanism of the PERM [programmgesteuerte elektronische Rechenanlage München]. —W. E. Proebster (pp. 353–359).

Printing the Results from Electronic Computers.—G. Overhoff (pp. 360–361).

Use of the Electronic Computer 'GAMMA 3' for solving Complicated Mathematical Problems.—H. Päsler (pp. 362–365).

Technical Problems in the Development of Magnetic-Drum Stores.—H. O. Leilich (pp. 365–368).

Store Resonator Circuit and Data Input and Output for the BULL Electronic Computer 'GAMMA 3'.—R. Machery (pp. 369–370).

Assessment of Quality of Rectangular [-loop] Ferrites for Electronic Computers.—O. Eckert, E. Weides & K. Wallenfang (pp. 371–374).

Development of Resistances for Electronic Apparatus. —H. Loth (pp. 375–376).

Transistors in Computer Technique.—A. Krösa & K. Ganzhorn (pp. 377–380).

Properties required in Germanium Diodes for Electronic Computers.—W. Bühler (pp. 381–382).

681.142 **1630**

**The Design, Construction and Applications of Electronic Digital Computers.**—E. Grundy & H. McG. Ross. (*Trans. S. Afr. Inst. elect. Engrs*, Oct. 1955, Vol. 26, Part 10, pp. 261–294.) A survey of the whole field, with a comprehensive bibliography; a wide range of actual and projected applications in science and industry is discussed, including process control and data analysis.

681.142: 621.314.7 **1631**

**A Transistor Digital Fast Multiplier with Magnetostrictive Storage.**—G. B. B. Chaplin, R. E. Hayes & A. R. Owens. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 121–124.) Discussion on 3170 of 1955.

681.142: 621.374.3 **1632**

**An Electrostatic Pulse Generator.**—W. Woods-Hill. (*Electronic Engng*, March 1956, Vol. 28, No. 337, pp. 122–123.) Pulse patterns required in electronic computers are generated by presenting a probe feeding a tuned amplifier to a suitably figured track on an insulated rotating drum carrying a r.f. voltage.

## CIRCUITS AND CIRCUIT ELEMENTS

621.3: 061.3/.4 **1633**

**1954 Western Electronic Show and Convention, Los Angeles, California.**—(*Trans. Inst. Radio Engrs*, Sept. 1954, PGCP-2, pp. 1–118.) The full text or an abstract is given of papers on various components, equipment and techniques presented at the Convention. Abstracts of all the papers are published in *Proc. Inst. Radio Engrs*, Dec. 1954, Vol. 42, No. 12, pp. 1819–1820.

621.3.011.22 **1634**

**The Resistance of Sheets, Strips, Wires, Tubes and Coils of Various Materials at Frequencies between 10 c/s and 100 kMc/s.**—J. Bachel, K. L. Lenz & O. Zinke. (*Frequenz*, Dec. 1955, Vol. 9, No. 12, pp. 401–406.) A method of calculation applicable to materials with widely different conductivities, ranging from Ag to Ge, is presented. The values of the resistance per square are found from sets of curves for material thicknesses of 0·1, 0·3 and 1 mm. Because of skin effect at high frequencies, the curves for these thicknesses cover all requirements.

621.316.82 **1635**

**Concavity of Resistance Functions.**—C. E. Shannon & D. W. Hagelbarger. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 42–43.) "It is proved that any



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network of linearly wound potentiometers and fixed resistors has a curve of resistance *versus* shaft angle which is concave downward."

621.318.4 **1636**

**Oscillations of Coupled Windings.**—P. A. Abetti, G. E. Adams & F. J. Maginniss. (*Elect. Engng, N.Y.*, Nov. 1955, Vol. 74, No. 11, p. 1002.) Digest of paper in *Trans. Amer. Inst. elect. Engrs*, Part III, *Power Apparatus and Systems*, April 1955, Vol. 74, pp. 12–21. By using the mutual-inductance function, the integral-equation method of determining the natural frequencies [3483 of 1954 (Abetti & Maginniss)] is extended to take account of the effect of a transformer secondary winding.

621.318.57: 621.3.042 **1637**

**The Transfluxor.**—J. A. Rajchman & A. W. Lo. (*Proc. Inst. Radio Engrs*, March 1956, Vol. 44, No. 3, pp. 321–332.) See 3509 of 1955.

621.372.029.6 **1638**

**Symposium on Microwave Strip Circuits.**—(See 1611.)

621.372.412 **1639**

**Variation with Temperature of Quartz Resonator Characteristics.**—R. Bechmann & V. Durana. (*Proc. Inst. Radio Engrs*, March 1956, Vol. 44, No. 3, p. 377.) Calculations based on the temperature variation of the piezoelectric constants of AT-, BT-, CT-, DT-, and X-cut quartz resonators indicate that the AT- and DT-cut resonators are particularly suitable for use, e.g. in filters, at temperatures as high as 250°C or over.

621.372.413 **1640**

**Theory of Electromagnetic Resonators of Almost Conical Shape.**—A. S. Kompaneets & Yu. S. Sayasov. (*Zh. tekh. Fiz.*, June 1955, Vol. 25, No. 6, pp. 1124–1131.) A mathematical investigation is carried out of E-mode oscillations in a resonator formed by a spheroid and a confocal two-sheet hyperboloid, for the case of a small ratio between the focal distance and the wavelength. Perturbation theory is modified to take into account the large deviation of the field from that in a resonator formed by a sphere and two coaxial cones.

621.372.413: 621.396.67 **1641**

**Theory of Thin Aerials in Cavity Resonators.**—A. V. Gaponov. (*Zh. tekh. Fiz.*, June 1955, Vol. 25, No. 6, pp. 1069–1084.) Free oscillations in a cavity resonator containing thin metallic aerials or having narrow slots in its walls are considered. Formulae are derived for the natural frequency and eigenfunctions of such a system and for the decrement and *Q* of the resonator. The results are used in a discussion of the excitation of a cavity resonator by thin aerials. The problem is reduced to the excitation of the resonator by given external electric or magnetic currents. Several examples are considered in detail. The analysis is continued in the following paper (*ibid.*, pp. 1085–1099); both tuned and untuned aerials are considered.

621.372.5 **1642**

**A Matrix Method in the Solution of Cascaded Four-Terminal Networks.**—R. E. Vowels. (*Aust. J. appl. Sci.*, Dec. 1955, Vol. 6, No. 4, pp. 427–441.)

621.372.5 **1643**

**The Geometrical Representation of the Parallel and the Series Reactance as a Loss-Free 'Parabolic' Quadripole.**—J. de Buhr. (*Nachrichtentech. Z.*, Dec. 1955, Vol. 8, No. 12, pp. 636–641.) Further application of the method described previously (349 of February and back references).

621.372.5: 621.396.822 **1644**

**Calculations with Noise Voltages: Part 2—Passage of Noise Voltages through Nonlinear Elements.**—G. Bosse. (*Frequenz*, Dec. 1955, Vol. 9, No. 12, pp. 407–413.) The correlation function is used to calculate the modification suffered by a noise spectrum on passing through a quadripole with nonlinear elements. The method is based on that of Rice (440, 2168 and 2169 of 1945). The quadripole characteristic is represented as an integral; the relation between the correlation functions for input and output voltages is in the form of a double integral which can be expanded in a power series. Simple expressions are obtained when the quadripole characteristic comprises a sum of Hermite polynomials. An introduction to the various parameters used is given in Part 1, *ibid.*, Aug. 1955, Vol. 9, No. 8, pp. 258–264.

621.372.54.029.6: 621.372.8 **1645**

**Design of [waveguide] Microwave Filters with Quarter-Wave Couplings.**—G. Craven & L. Lewin. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 173–177.) "Resonator diaphragms are constructed from triplets of inductive posts, whose spacings and radii are chosen to prevent the generation of the first five non-propagating modes. This is sufficient to ensure negligible coupling at quarter-wave separation. Measurements on filters at 4 000 Mc/s indicate a satisfactory performance."

621.372.542.2 **1646**

**Normalized Filter Design.**—S. D. Bedrosian & R. McCoy, Jr. (*Electronics*, March 1956, Vol. 29, No. 3, pp. 200–202, 204.) The design chart presented for composite low-pass filters permits predetermining the attenuation characteristic from trial design. Six normalized designs are presented as examples to cover a practical range of stop-band loss.

621.372.56.029.63/.64: 538.569.3 **1647**

**R.F. Attenuators and Load Materials.**—D. Lichtman. (*Tele-Tech & Electronic Ind.*, Nov. 1955, Vol. 14, No. 11, Section 1, pp. 88, 126 . . 129.) The preparation of iron-araldite mixtures with ratios of 1 : 1 to 8 : 1 by weight is described and results of loss measurements in the frequency range 1·5–7·5 kMc/s are reported. The results are presented graphically.

621.373: 621.396.822 **1648**

**A Comparison of the Noise, and Random Frequency and Amplitude Fluctuations in Different Types of Oscillator.**—R. L. Beurle. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 182–189.) "The nature of the random fluctuation in the output is dependent on the form of feedback employed and the method by which the output amplitude is controlled. The frequency band over which the output power is distributed depends, however, on the relative magnitudes of signal and noise in the circuit rather than on the particular circuit employed. The conclusion is that an oscillator should be operated at as high a level as possible consistent with stability and constancy of the circuit components."

621.373.4: 621.396.822: 621.376.3 **1649**

**Frequency Modulation Noise in Oscillators.**—J. L. Stewart. (*Proc. Inst. Radio Engrs*, March 1956, Vol. 44, No. 3, pp. 372–376.) The discussion is confined to noise due to the discrete nature of the electron and the random motion of the electrons in the oscillator valve; the spectrum ranges from zero to hundreds of Mc/s. The effect of the usual band-pass filter on the noise modulation is determined and the power spectrum of the oscillator output is evaluated. The theory is applied to several types of oscillator.



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621.373.421 : 621.376.32 1650

**A Wide-Band Frequency-Modulated System with Asymmetrical 3-Phase Oscillator.**—P. Kundu. (*Indian J. Phys.*, March 1955, Vol. 29, No. 3, pp. 151–160.) An analytical investigation is made of the operation of the 3-phase *RC* oscillator; symmetrical and asymmetrical arrangements are compared as regards linearity of modulation, modulation sensitivity and frequency stability in a f.m. system.

621.373.43 1651

**A Phase-Controlled Oscillator.**—P. G. Davis. (*Electronic Engng*, March 1956, Vol. 28, No. 337, pp. 101–105.) Description of an oscillator whose frequency is an exact multiple of the mains frequency; the phase relation is maintained constant by a feedback loop and phase comparator.

621.373.43 1652

**A Particular Mode of Relaxation Oscillation in a Triode Valve.**—R. Bedos & P. Jean. (*C. R. Acad. Sci., Paris*, 9th Jan. 1956, Vol. 242, No. 2, pp. 234–236.) Operation of an arrangement with a very high resistance between the grid and the point of application of grid voltage is discussed. The $I_a/V_g$ characteristic is two-valued, giving rise to relaxation oscillations. See also 3172 of 1954 (Jean).

621.373.431.2 : 621.314.7 1653

**Junction Transistors with Alpha Greater than Unity.**—Schenkel & Statz. (See 1893.)

621.373.52 : 621.314.7 1654

**Transistorizing Meacham-Bridge Oscillators.**—S. N. Witt, Jr. (*Electronics*, March 1956, Vol. 29, No. 3, pp. 193–195.) 1955 National Electronics Conference paper. Highly stable circuits using either point-contact or junction transistors are described, for operation at a frequency of 1 Mc/s.

621.374.3 1655

**Experiments on the Regeneration of Binary Microwave Pulses.**—O. E. DeLange. (*Bell Syst. tech. J.*, Jan. 1956, Vol. 35, No. 1, pp. 67–90.) A device consisting of a waveguide hybrid junction with a Si crystal diode in each arm, working at signal frequency (4 kMc/s), gives sufficient regeneration to permit transmission of signals over a long chain of repeaters, providing that the r.m.s. signal/noise ratio at each repeater is $>$ 20 dB.

621.374.32 : 621.314.7 1656

**High-Speed Counter uses Surface-Barrier Transistor.**—E. Gott. (*Electronics*, March 1956, Vol. 29, No. 3, pp. 174–178.) The complete circuit is given of a four-stage reversible binary counter used for decoding p.c.m. signals. The high $\alpha$-cut-off frequency of the surface-barrier transistors employed permits the attainment of a counting rate of $6 \times 10^6$ pulses/sec.

621.374.4 : 621.396.91 1657

**Time-Signal Generator employing Decade-Counting Tubes.**—Y. Suguri, T. Ichida & K. Harada. (*J. Radio Res. Labs, Japan*, July 1955, Vol. 2, No. 9, pp. 235–238.) In a frequency-dividing circuit operated in conjunction with a frequency standard and using two decade counters to effect the last stages of division from 100 c/s to 1 c/s, fluctuation of delay time for the leading edge of the seconds output pulse is 3·5 $\mu$s, and for the trailing edge 0·1 $\mu$s or better.

621.375.2 + 621.373.4 + 621.317.3].029.6 1658

**Disc-Seal Circuit Techniques.**—J. Swift. (*J. Brit. Instn Radio Engrs*, Dec. 1955, Vol. 15, No. 12, pp. 607–622 & Feb. 1956, Vol. 16, No. 2, pp. 95–111.) Reprint. See 3541 of 1955.

621.375.23 : 621.314.222 1659

**Stability Problems with Low-Frequency Amplifiers with Transformers in the Feedback Path.**—W. Langsdorff. (*Frequenz*, Nov. & Dec. 1955, Vol. 9, Nos. 11 & 12, pp. 369–379 & 422–428.) Measurements were made of the attenuation and phase variation of typical push-pull output transformers over the frequency band 20–200 kc/s, outside the low-frequency band; the phase variation was compared with that of a minimum-phase-rotation network with the same attenuation variation. The results indicate the possibility of simplifying the stability testing of the amplifier circuit by testing the transformer as a minimum-phase-rotation network.

621.375.3 : 621-526 1660

**Self-Balancing Magnetic Servo Amplifier.**—W. A. Geyger. (*Electronics*, March 1956, Vol. 29, No. 3, pp. 196–199.) "Positive magnetic and negative electric feedback improve performance of single-stage magnetic servo amplifier driving two-phase 400-c/s induction motor and standard position servomechanism."

621.375.3 : 621.318.57 1661

**Magnetic Amplifiers in Bistable Operation.**—L. A. Finzi & G. C. Feth. (*Elect. Engng, N.Y.*, Nov. 1955, Vol. 74, No. 11, p. 1008.) Digest of paper in *Trans. Amer. Inst. elect. Engrs*, Part 1, *Communication and Electronics*, 1955, Vol. 74. Flip-flop operation can be achieved by over-regenerative feedback. The relation of the switching cycle to the steady-state transfer characteristic is examined.

621.375.4 : 621.314.7 1662

**A Study of Transistors connected in Parallel.**—A. N. Daw. (*Indian J. Phys.*, March 1955, Vol. 29, No. 3, pp. 121–130.) The performance of the parallel combination of transistors is studied in terms of a single equivalent transistor whose parameters are related in a simple manner to those of the individual transistors. Expressions are derived for the gain and the input and output impedances for the three basic modes of operation. Results of experiments with both point-contact and junction types are in good agreement with the theoretical results.

621.375.4 : 621.376.22 : 621.314.63 1663

**A Silicon Junction Diode Modulator.**—N. F. Moody. (*Electronic Engng*, March 1956, Vol. 28, No. 337, pp. 94–100.) By the use of biased diodes in a specially designed bridge circuit, d.c. is converted to a.c. over a range from audio frequencies to at least 100 kc/s, with a zero stability of better than $10^{-10}$ W at room temperature and $10^{-8}$ W at 80° C.

621.376.23 : 538.569.4 1664

**Theory of the Autodyne Detector for Paramagnetic Resonance.**—F. Bruin & F. M. Schimmel. (*Physica*, Nov. 1955, Vol. 21, No. 11, pp. 867–876. In French.)

## GENERAL PHYSICS

53.081.4 1665

**Use of Logarithmic Notation in Science and Engineering.**—S. Devons. (*Nature, Lond.*, 25th Feb. 1956, Vol. 177, No. 4504, pp. 373–374.) A unit for general logarithmic systems is proposed, termed the 'jot'; the notation used is: $x$ = (unit + $xyz.ab$) jot, but the word 'jot' is normally omitted. Advantages of the



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system are simplicity of calculation, economy of notation, simplification of units, and simplification of representation of errors. Examples of use of the notation are given.

535.1 **1666**

**Correlation between Photons in Two Coherent Beams of Light.**—R. H. Brown & R. Q. Twiss. (*Nature, Lond.*, 7th Jan. 1956, Vol. 177, No. 4497, pp. 27–29.) Principles used in the radio interferometer described previously (103 of 1955) are applicable to the measurement of the angular diameter of visual stars if the two aerials are replaced by mirrors and the r.f. detectors by photocells. For operation of such a system it is essential that the time of arrival of photons at the two photocathodes should be correlated when the light beams incident on the two mirrors are coherent; a laboratory experiment demonstrating the existence of this effect is described.

535.13 **1667**

**Asymptotic Solutions of Maxwell's Equations involving Fractional Powers of the Frequency.**—M. Kline. (*Commun. pure appl. Math.*, Nov. 1955, Vol. 8, No. 4, pp. 595–614.) The principal theorem derived indicates the method of obtaining steady-state solutions, provided that the behaviour of the corresponding pulse solutions in the neighbourhood of the singularities is known.

535.231 : 536.7 **1668**

**Mathematical Study of Boltzmann's Equation.**—S. Marquet. (*C. R. Acad. Sci., Paris*, 30th Jan. 1956, Vol. 242, No. 5, pp. 615–617.)

535.42 : 538.566 **1669**

**Diffraction by a Plane Aperture with Variable Contour. General Formulae.**—O. Costa de Beauregard. (*C. R. Acad. Sci., Paris*, 16th Jan. 1956, Vol. 242, No. 3, pp. 347–350.) Four-dimensional extension of the formulae of classical diffraction theory [2909 of 1954 (Bouwkamp)].

537.211 **1670**

**Some Theoretical and Practical Considerations of the Johnsen-Rahbek Effect.**—A. D. Stuckes. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 125–131.) The Johnsen-Rahbek effect which is observed when a voltage is applied between metal and semiconductor surfaces in 'contact' with one another is explained as due to the e.s. force across the gap, which exists at all points except a few where contact is actually made. The force increases with the voltage until the latter reaches the critical value causing field emission. Experiments with a clutch based on this effect are described; the results indicate that such a device would be too unreliable for practical purposes; the effect might be used in relays and gas-flow valves.

537.226 **1671**

**Dielectric Properties of a Lattice of Anisotropic Particles.**—Z. A. Kaprielian. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 24–32.) Analysis is presented for a uniform lattice of similarly oriented particles of arbitrary shape and material. The packing density is assumed to be such that interaction between particles must be considered but the induced fields can still be regarded as simple dipole fields. Two particular cases are examined: (*a*) a cubic array of ferrite spheres, and (*b*) a tetragonal array of disks; in the latter case the calculated values of dielectric constant are in good agreement with experimental results reported by [El-] Kharadly & Jackson (2902 of 1953).

537.311.31 : 535.215 **1672**

**Electronic Interaction between Adsorbed Gas Molecules and Metal Surfaces.**—R. Suhrmann. (*Z. Metallkde*, Nov. 1955, Vol. 46, No. 11, pp. 780–786.) The interaction is discussed in terms of the structure of the gas molecules and the work function of the metal. Experimental investigations based on the variation of photoelectric sensitivity and resistance of thin films of the metal on adsorption of the gas are described. Metals used were Ni and Pt, gases were O, H, N, $CO_2$, $N_2O$, water vapour and benzene vapour. The investigation is relevant to the problem of conduction at the surface of semiconductors.

537.5 **1673**

**The Diffusion of Electrons in a Gas at Low Temperatures.**—B. I. H. Hall. (*Aust. J. Phys.*, Dec. 1955, Vol. 8, No. 4, pp. 551–554.) Laboratory measurements were made of electron agitation energy $Q$ as a function of $Z/n$ and $Q_0$, where $Z$ is an applied electric field, $n$ the concentration of gas molecules and $Q_0$ the mean agitation energy of the molecules. The gases used were $N_2$ and $H_2$.

537.52 **1674**

**International Symposium on Electrical Discharges in Gases.**—(*Appl. sci. Res.*, 1955, Vol. B5, Nos. 1–4, pp. 1–344.) The text is given of 66 papers presented at the symposium held at Delft in April 1955. The subjects discussed included (*a*) fundamental processes in gas discharges, (*b*) instabilities and oscillations in gas discharges, (*c*) high-frequency discharges and the dependence of breakdown on frequency and on the product of pressure and electrode separation, (*d*) methods of measurement, (*e*) arc discharges, and (*f*) spark discharges.

537.525 **1675**

**Study of the Induced Electric Discharge in Rare Gases.**—F. Cabannes. (*Ann. Phys., Paris*, Nov./Dec. 1955, Vol. 10, pp. 1026–1078.) Experiments were performed using a tube of a few centimetres diameter and a frequency of 1 Mc/s. Aspects investigated included the conditions for starting the discharge and the radiation from the discharge. Theory is developed giving a quantitative explanation of the experimental results. See also 2915 of 1954 and *Appl. sci. Res.*, 1955, Vol. B5, Nos. 1–4, pp. 318–320.

537.533/.534 **1676**

**Penetration of Electrons and Ions in Aluminium.**—J. R. Young. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 1–4.) "The depth of penetration of 0·5- to 11-keV electrons and 1- to 25-keV $H^+$, $H_2^+$, and $He^+$ ions in aluminium has been measured. It has been found that the Thompson-Whiddington law for electrons does not hold for electrons having energies less than 10 keV. The practical range-energy relation obtained for electrons in aluminium was found to be $R = KE^{1 \cdot 3}$, where $K$ is 0·042 if $E$ is expressed in keV and $R$ in microns. The practical range-energy relation for light ions in aluminium was found to be $R = KE^{0 \cdot 83}$ where $K = 0{\cdot}020$ for $H^+$, $K = 0{\cdot}021$ for $He^+$, and $K = 0{\cdot}015$ for $H_2^+$ . . . Results are compared with those obtained by previous observers."

537.533 **1677**

**Use of the Knife-Edge Method to determine Aberrations of Deflected Electron Beams.**—H. Grümm. (*Optik, Stuttgart*, 1955, Vol. 12, No. 12, pp. 544–553.) The beam is caused to throw a shadow of a knife-edge or wire on a distant plane. Theory is given and selected shadow pictures are reproduced.



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537.533.7 1678

**Collective Oscillations and Characteristic Electron-Energy Losses.**—D. Gabor. (*Phil. Mag.*, Jan. 1956, Vol. 1, No. 1, pp. 1–18.) An attempt is made to give a simple theory of the interaction of fast electrons with thin films of solids, adequate for interpreting results of past experiments and for suggesting new, crucial tests.

537.533.8 : 546.45 1679

**Secondary Electron Emission from Thin Layers of Be: Part 2.**—I. M. Bronshtein & T. A. Smorodina. (*Zh. eksp. teor. Fiz.*, Oct. 1955, Vol. 29, No. 4 (10), pp. 495–499.) An experimental investigation is reported of the secondary-electron emission coefficient $\sigma$ and the variation of secondary-electron energy distribution with the thickness of thin layers of Be. For approximately monatomic layers of Be on Ni or Ag and constant primary electron energy, the secondary electron energy, $E_r$, at which the maximum of the $d\sigma/dE_r$ versus $E_v$ curve occurs is a minimum. Part 1: 684 of 1955.

537.533.8 : 546.57 1680

**Secondary Electron Emission from Thin Layers of Silver.**—I. M. Bronshtein & T. A. Smorodina. (*Zh. eksp. teor. Fiz.*, Oct. 1955, Vol. 29, No. 4 (10), pp. 500–506.) An experimental investigation of Ag films on Ni or Be base. See also 1679 above.

537.56 : 538.56 : 537.311.33 1681

**Plasma Oscillations at Extremely High Frequencies.**—M. A. Lampert. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 5–11.) The analysis presented is applicable to plasmas in impurity semiconductors as well as those in gas discharges. The design of mm-$\lambda$ generators based on standing waves in such plasmas is considered; electron densities of the order of $10^{15}/cm^3$ are required. In a system discussed, an electron beam is shot into the plasma, which is confined between two parallel reflecting surfaces; these may be the faces of a wafer of semiconductor whose thickness determines the natural oscillation frequency. Problems introduced by the slowing-up of the electron beam in such a system are indicated.

538.1 1682

**Magnetic Systems associated with Systems of Permanent Electric Currents and their Application to the Numerical Calculation of Fields.**—É. Durand. (*Ann. Phys., Paris*, Nov./Dec. 1955, Vol. 10, pp. 883–907.) By superposing magnetic shells associated with the elementary tubes corresponding to an arbitrary distribution of currents, the associated magnetic systems are simply determined. In this way a scalar potential inside the currents can be defined. See also 3229 of 1955.

538.1 1683

**Derivation of an Expression for the Scalar Potential of a Line Current in the Form of a Curvilinear Integral.**—É. Durand. (*C. R. Acad. Sci., Paris*, 4th Jan. 1956, Vol. 242, No. 1, pp. 78–81.)

538.13 1684

**Calculating the Distance between Equivalent Poles of a Bar Magnet.**—J. R. Boggs. (*Trans. Amer. geophys. Union*, June 1955, Vol. 36, No. 3, pp. 487–488.)

538.221 1685

**The Barkhausen Effect.**—R. S. Tebble. (*Proc. phys. Soc.*, 1st Dec. 1955, Vol. 68, No. 432B, pp. 1017–1032.) The only feasible mechanism to account for the phenomena associated with the Barkhausen effect is one in which the movement of a limited section of a 180° domain boundary is delayed by a nonmagnetic inclusion whose cross-sectional dimensions lie within the range $1$–$2 \times 10^{-5}$ cm. Hysteresis losses in ferromagnetic materials may be reduced by the selective reduction of the number of inclusions whose size is within this critical range.

538.221 1686

**Temperature Dependence of Ferromagnetic Anisotropy in Cubic Crystals.**—F. Keffer. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1692–1698.) Theories advanced by Zener and by Van Vleck are reconciled; they afford, respectively, low- and high-temperature approximations to the same physical picture, namely, an anisotropy decreasing with rising temperature, due to statistical fluctuations from alignment of anisotropically coupled neighbour spins.

538.3 : 52 1687

**A Discussion on Magneto-hydrodynamics.**—(*Proc. roy. Soc. A*, 29th Dec. 1955, Vol. 233, No. 1194, pp. 289–406.) The text is given of papers presented at the discussion noted previously [3577 of 1955 (Ferraro)].

538.3 : 537.56 1688

**Some Exact Solutions of the Lorentz Invariant Problem of the Motion of Two Electric Fluids.**—J. J. Gibbons. (*Canad. J. Phys.*, Dec. 1955, Vol. 33, No. 12, pp. 819–823.)

538.566 : 535.42 1689

**Some Problems on Obstacles placed in the Path of Electromagnetic Radiation.**—M. Bouix. (*Ann. Télécommun.*, Nov. & Dec. 1955, Vol. 10, Nos. 11 & 12, pp. 243–251 & 254–260.) The relations between the incident, reflected and refracted fields at the surface separating two media are studied using vectorial analysis with a system of coordinates attached to the surface. Both media may be dielectrics or one may be conducting. The plane separating surface is discussed first and the analysis is extended to treat diffraction by a sphere; exact formulae are derived for the re-radiation gain and the total diffusion surface.

538.566 : 535.43 1690

**Tensor Scattering Matrix for the Electromagnetic Field.**—D. S. Saxon. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1771–1775.) Theory presented previously 3105 of 1954 (Gerjuoy & Saxon) is extended to treat the vector field and to include absorption.

538.566 : 537.56 1691

**Interaction of Centimetre Waves with a Plasma in the Presence of a Magnetic Field.**—F. Diamand, A. Gozzini & T. Kahan. (*C. R. Acad. Sci., Paris*, 4th Jan. 1956, Vol. 242, No. 1, pp. 90–93.) Experimental evidence of self-interaction was sought, using an a.m. wave of frequency 10 kMc/s in a circular waveguide containing a continuous discharge parallel to the direction of propagation and a transverse magnetic field. Absorption was observed, passing through a maximum at the field-strength value corresponding to the gyrofrequency. An expression for the modulation depth is derived in terms of carrier frequency, gyrofrequency and modulation frequency. The term 'self-interaction' is preferred to 'self-demodulation' since the modulation depth may be either increased or decreased, depending on the circumstances. Further experiments were made by transmitting an unmodulated 10-kMc/s



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wave through a plasma oscillating at low frequency in a neon tube of length 30 cm. The r.f. wave became strongly modulated; the form of the wave envelope was modified greatly by application of a magnetic field, while the modulation disappeared completely at the field strength corresponding to gyromagnetic resonance.

538.569.4 **1692**

**Absorption of Microwaves and U.H.F. Radio Waves in Phenol, Cyclohexanol and 1-Bromo 2-Chloroethane.**—D. K. Ghosh. (*Indian J. Phys.*, April 1955, Vol. 29, No. 4, pp. 161–166.)

538.569.4: 535.33: 546.171.1 **1693**

**New Method for the Observation of Hyperfine Structure of $NH_3$ in a 'Maser' Oscillator.**—K. Shimoda & T. C. Wang. (*Rev. sci. Instrum.*, Dec. 1955, Vol. 26, No. 12, pp. 1148–1149.)

538.569.4: 539.15 **1694**

**Nuclear Magnetic Resonance in Very Weak Fields.**—(*Helv. phys. Acta*, 15th Dec. 1955, Vol. 28, No. 7, pp. 617–632. In French.)

Part 1—A Radio Spectroscope for Observation of Resonance between 15 and 2 kc/s.—C. Manus, G. Béné, R. Extermann & R. Mercier (pp. 617–625). The apparatus is described in detail. The signal/noise ratio is calculated and the result compared with values obtained experimentally.

Part 2—Study of Nuclear Magnetic Resonance between 2 and 0·5 Gauss.—B. Cagnac, C. Manus, G. Béné & R. Extermann (pp. 626–632). Proton-resonance experiments are described. Variation of resonance curves with h.f. amplitude and with the characteristics of the scanning field is investigated.

538.569.4: 621.376.23 **1695**

**Theory of the Autodyne Detector for Paramagnetic Resonance.**—F. Bruin & F. M. Schimmel. (*Physica*, Nov. 1955, Vol. 21, No. 11, pp. 867–876. In French.)

538.569.4.029.6: 621.372.413 **1696**

**Observation of Nuclear Quadrupole Resonances with a Coaxial-Cavity Spectrometer.**—S. Kojima, A. Shimauchi, S. Hagiwara & Y. Abe. (*J. phys. Soc. Japan*, Nov. 1955, Vol. 10, No. 11, pp. 930–933.) A note on the construction of a spectrometer based on a two-cavity klystron oscillator, and its operation in the range 700 Mc/s–1 kMc/s.

538.691 **1697**

**The Stability of the Equilibrium Configuration of a Current-Carrying Wire in a Magnetic Field.**—C. Bernardini. (*R. C. Accad. naz. Lincei*, Nov. 1955, Vol. 19, No. 5, pp. 297–301.) The problem is considered in relation to the investigation of the trajectories of charged particles by the floating-wire method, as discussed by Loeb (78 of 1947). Analysis shows that in certain cases when the field has focusing properties the configuration of the wire is unstable. Application of the results to a betatron problem is briefly indicated.

## GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

52: 538.3 **1698**

**A Discussion on Magneto-hydrodynamics.**—(See 1687.)

523: 538.69 **1699**

**Interplanetary Magnetic Fields and Cosmic Rays.**—L. Davis, Jr. (*Phys. Rev.*, 1st Dec. 1955, Vol. 100, No. 5, pp. 1440–1444.) A discussion of the implications of the hypothesis that, as a result of solar corpuscular emission, a field-free region is produced round the sun, with a mean radius of the order of 200 times the distance between the sun and the earth.

523.16 **1700**

**The Measurement of the Angular Diameter of Two Intense Radio Sources.**—R. C. Jennison & M. K. Das Gupta. (*Phil. Mag.*, Jan. 1956, Vol. 1, No. 1, pp. 55–75.) An interferometer using post-detector correlation is described and results of measurements of the diameter and structure of the radio stars Cygnus A and Cassiopeia A are given. The interferometer operates on 116·5, 125 or 132·5 Mc/s and uses aerials spaced at up to 12 km, the remote aerial being connected via an 83-Mc/s radio link to the correlator.

523.16 **1701**

**Apparent Intensity Variations of the Radio Source Hydra-A.**—O. B. Slee. (*Aust. J. Phys.*, Dec. 1955, Vol. 8, No. 4, pp. 498–507.) Over a period of 12 months about 200 observations of the intensity of Hydra-A were compared with observations on other strong r.f. sources. The results indicate that Hydra-A is relatively much more variable, though no periodic changes have been detected. Possible mechanisms producing the intensity changes are considered.

523.16 **1702**

**Rotation and other Motions of the Magellanic Clouds from Radio Observations.**—F. J. Kerr & G. de Vaucouleurs. (*Aust. J. Phys.*, Dec. 1955, Vol. 8, No. 4, pp. 508–522.) The motions have been studied by means of 21-cm-$\lambda$ line radiation from interstellar hydrogen.

523.16 **1703**

**The Angular Size of the Variable Radio Source Hydra-A.**—A. W. L. Carter. (*Aust. J. Phys.*, Dec. 1955, Vol. 8, No. 4, pp. 564–567.) Preliminary observations on 101 Mc/s suggest that the size as well as the intensity of this source varies. See also 1701 above.

523.72 + 523.32]: 538.56.029.6 **1704**

**Observations of Solar and Lunar Radiation at 1·5 Millimeters.**—W. M. Sinton. (*J. opt. Soc. Amer.*, Nov. 1955, Vol. 45, No. 11, pp. 975–979.) Further observations have been made using the method described previously (3076 of 1952). Measured values of atmospheric absorption are greater than values of water-vapour absorption calculated by Van Vleck (3100 of 1947). The transmittances of some materials at 1·5 mm are tabulated.

523.72: 551.593.5 **1705**

**Investigation of Sky Brightness in the Spectral Region near 1 $\mu$ during the Solar Eclipse of 30th June 1954.**—S. F. Rodionov & E. D. Sholokhova. (*C. R. Acad. Sci. U.R.S.S.*, 1st Dec. 1955, Vol. 105, No. 4, pp. 676–679. In Russian.) The variation of the atmospheric infrared radiation excited by the incident solar ultraviolet radiation was investigated. Intensity variations observed at wavelengths of 1 $\mu$ and 0·71 $\mu$ indicate that the radiation from the corona is richer in ultraviolet than the radiation from the sun as a whole.

523.72: 621.396.822 **1706**

**The Distribution of Radio Brightness over the Solar Disk at a Wavelength of 21 Centimetres: Part 3—The Quiet Sun—Two-Dimensional Observations.**—W. N. Christiansen & J. A. Warburton.



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(*Aust. J. Phys.*, Dec. 1955, Vol. 8, No. 4, pp. 474–486.) The observations reported in Part 2 (715 of 1954) are extended by using two multiple interferometers arranged at right angles, thus enabling the solar disk to be scanned in many different directions. From the data thus obtained the two-dimensional brightness distribution is reconstructed by a Fourier-analysis method. Marked limb-brightening in the equatorial zones is indicated, but none in the polar regions.

523.72: 621.396.822 **1707**

**Solar Brightness Distribution at a Wavelength of 60 Centimetres: Part 1—The Quiet Sun.**—G. Swarup & R. Parthasarathy. (*Aust. J. Phys.*, Dec. 1955, Vol. 8, No. 4, pp. 487–497.) Observations were made with a 32-element interferometer to check Stanier's results (1401 of 1950) obtained with a two-aerial interferometer. The observed limb-brightening is reasonably consistent with that reported by O'Brien & Tandberg-Hanssen (2607 of 1955), whereas Stanier found no limb-brightening. The divergences may be related to actual differences consequent on the changing phase of the solar cycle.

550.385: 523.7: 523.165 **1708**

**Correlation among Magnetic Storms, Solar Phenomena and Cosmic-Ray Storms.**—Y. Sekido, M. Wada, I. Kondoh & K. Kawabata. (*Rep. Ionosphere Res. Japan*, Sept. 1955, Vol. 9, No. 3, pp. 174–180.)

551.510.535 **1709**

**Movements in the Ionosphere.**—J. A. Ratcliffe. (*Nature, Lond.*, 18th Feb. 1956, Vol. 177, No. 4503, pp. 307–308.) Report of Royal Astronomical Society discussion held in November 1955. Methods of measuring the movements and results obtained are briefly indicated. An important piece of new information about the lower F region is that simultaneous observations on large-scale ripples and on the small-scale irregularities producing fading show that these two types of irregularity travel with the same speed.

551.510.535 **1710**

**Movement of Sporadic-E Ionization.**—J. A. Harvey. (*Aust. J. Phys.*, Dec. 1955, Vol. 8, No. 4, pp. 523–534.) "The horizontal movement of patches of daytime sporadic E ionization has been observed by using a system of spaced pulse transmitters and a central recorder. The directions of movement are mainly towards the north and west, with speeds mainly between 40 and 80 m/sec. These velocities differ in direction from the F region disturbances recorded at the same time and have only about half the speed."

551.510.535 **1711**

**Electronic Collisional Frequency in the F-Region over Calcutta.**—S. Datta. (*Indian J. Phys.*, June 1955, Vol. 29, No. 6, pp. 279–284.) Determinations of the collision frequency were made on the basis of Appleton's formula relating ionosphere reflection coefficient with the difference between the group and optical wave paths within the region. Values corresponding to different heights in the F layer are tabulated. The 'most probable' value is $3 \cdot 8 \times 10^3$ per sec per electron.

551.510.535 **1712**

**On the Influence of Electron-Ion Diffusion on the Electron Density and Height of the Nocturnal $F_2$ Layer (Supplement).**—T. Yonezawa. (*J. Radio Res. Labs, Japan*, July 1955, Vol. 2, No. 9, pp. 281–291.) The influence of the earth's magnetic field on electron-ion diffusion will tend to reduce the atmospheric density in the $F_2$ region at night; a lower limit for the maximum density of $3 \times 10^9$ cm$^{-3}$, or 60% of the value suggested in the earlier paper (751 of March), is possible. Other considerations tend to confirm the value of $5 \times 10^9$ cm$^{-3}$ originally suggested, which agrees with extrapolations from rocket data if the true height of the $F_2$ layer is about 200 km.

551.510.535 **1713**

**On the Occurrence of Spread Echoes in the F Region over Japan.**—I. Kasuya, S. Katano & S. Taguchi. (*J. Radio Res. Labs, Japan*, July 1955, Vol. 2, No. 9, pp. 329–339.) Analysis of published ionospheric data for Japan for the period 1949–1954 suggests that spread echoes occur more frequently in the north than in the south, chiefly at night, at the solstices and when solar activity is weak. Echoes of the most common type are attributed to reflections from irregularities in the upper regions of the F layer which are normally masked in daytime; others may be due to reflections from turbulences during magnetic storms, or to ionized clouds passing through the normal layer.

551.510.535 **1714**

**Photoelectric Studies of the Night Sky Light: Part 4.**—M. Huruhata, H. Tanabe & T. Nakamura. (*Rep. Ionosphere Res. Japan*, Sept. 1955, Vol. 9, No. 3, pp. 136–147.) An attempt is made to correlate variations of night-glow intensity with those of electron density in the $F_2$ layer; the results are inconclusive.

551.510.535: 001.4 **1715**

**Russian Ionosphere Terminology.**—G. F. Schultz. (*Proc. Inst. Radio Engrs*, March 1956, Vol. 44, No. 3, p. 376.) Russian equivalents are given for about 30 English terms.

551.510.535: 523.78: 550.385 **1716**

**Effect of the Solar Eclipse on the Lower Parts of the Ionosphere and the Geomagnetic Field.**—T. Nagata, Y. Nakata, T. Rikitake & I. Yokoyama. (*Rep. Ionosphere Res. Japan*, Sept. 1955, Vol. 9, No. 3, pp. 121–135.) Changes in E-layer electron density observed at a number of stations during the solar eclipse of 9th May 1948 have been examined and the resulting changes in conductivity deduced. The effects are found to exist over a very much wider area than that eclipsed. The calculated modifications in the $S_q$ current consequent upon the electron-density changes provide a satisfactory quantitative explanation of changes in the earth's magnetic field at the time of the eclipse.

551.510.535: 525.624 **1717**

**Lunar Tide in Sporadic E at Brisbane.**—J. A. Thomas & A. C. Svenson. (*Aust. J. Phys.*, Dec. 1955, Vol. 8, No. 4, pp. 554–556.) An analysis has been made of night-time values of $h'E_s$ for the period December 1952–November 1953; results are tabulated and plotted on a 12-hour harmonic dial. The semidiurnal variation has a mean amplitude of 0·69 km and a mean phase of 6·7 h. Results are compared with those of Martyn (1052 of 1949) and Matsushita (408 of 1954).

551.510.535: 550.385 **1718**

**The Electrical Conductivity of the Ionosphere and Disturbances of the Geomagnetic Field at Audio and Lower Frequencies.**—G. Grenet. (*C. R. Acad. Sci., Paris*, 16th Jan. 1956, Vol. 242, No. 3, pp. 401–403.) On the basis of assumed values for collision frequency and maximum electron density for the E, $F_1$ and $F_2$ layers, values are calculated for the conductivity parallel and perpendicular to the magnetic field, and for periods corresponding to certain critical frequencies.



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The significance of the results is discussed in relation to the possibility of extraterrestrial origins for geomagnetic-field disturbances.

551.510.535: 550.385 **1719**

**Daily Variations of the Electrical Conductivity of the Upper Atmosphere as deduced from the Daily Variations of Geomagnetism: Part 1—Equatorial Zone.**—H. Maeda. (*Rep. Ionosphere Res. Japan*, Sept. 1955, Vol. 9, No. 3, pp. 148–165.)

551.510.535: 550.385 **1720**

**Studies on the Disturbances in $F_2$ Layer associated with Geomagnetic Disturbances.**—K. Sinno. (*Rep. Ionosphere Res. Japan*, Sept. 1955, Vol. 9, No. 3, pp. 166–173.) Reports on work published previously (3303 of 1953 and 3258 of 1955) are collected and discussed.

551.510.535: 621.396.11 **1721**

**Radio Observations of the Ionosphere at Oblique Incidence.**—Chapman, Davies & Littlewood. (See 1850.)

551.594.5 **1722**

**Preliminary Studies of the Distribution of Auroras in Alaska.**—C. T. Elvey, H. Leinbach, J. Hessler & J. Noxon. (*Trans. Amer. geophys. Union*, June 1955, Vol. 36, No. 3, pp. 390–394.) "The analysis of auroral observations for 1951–53 from five stations spread over Alaska shows a zone at geomagnetic latitude 68° for which the incidence of auroras is independent of magnetic activity. At geomagnetic latitudes south of 67°, the incidence of auroras is markedly dependent upon magnetic activity."

551.594.5 **1723**

**Auroral Heights over West-Central Canada.**—B. W. Currie. (*Canad. J. Phys.*, Dec. 1955, Vol. 33, No. 12, pp. 773–779.) Results of an analysis of parallactic photographs of aurorae taken in 1933 at Chesterfield (63·3°N, 90·7°W) suggest that auroral heights in this region are slightly greater than those observed from Norway. There is no definite evidence of a change of height with time after sunset.

551.594.6 **1724**

**Observations of Whistling Atmospherics at Geomagnetically Conjugate Points.**—M. G. Morgan, H. E. Dinger & G. McK. Allcock. (*Nature, Lond.*, 7th Jan. 1956, Vol. 177, No. 4497, pp. 29–31.) Comparison of records obtained at points in N. America and in New Zealand appear to confirm Storey's theory (142 of 1954) that 'whistlers' and 'swishes' are produced as the atmospherics travel along the dispersive paths constituted by the geomagnetic flux lines between the northern and southern hemispheres.

## LOCATION AND AIDS TO NAVIGATION

621.396.93: 621.396.677.51: 621.318.134 **1725**

**Ferrite Aerials in Goniometer Direction Finders.**—Ziehm. (See 1622.)

621.396.96 + 621.396.93 **1726**

**Symposium on Marine Communications and Navigation.**—(*Trans. Inst. Radio Engrs*, March 1955, Vol. CS-3, No. 1, pp. 1–72.) The full text is given of 24 papers presented at the symposium held at Boston, Mass., in October 1954. The subjects discussed included electronic aids to the fishing industry, and the need for further developments and supplementary techniques in radar.

621.396.96 **1727**

**A Radar System for Harbour Surveillance.**—A. Leconte. (*Onde élect.*, Dec. 1955, Vol. 35, No. 345, pp. 1147–1152.) Shore-based radar systems for harbour control are discussed and the installation at Dunkirk is described; the frequency used is between 9·345 and 9·410 kMc/s. Identification of ships by means of transponder beacons, either permanently installed or carried to the ship by the pilot, is suggested.

621.396.96 **1728**

**Radar Warning Net uses Centralized Control.**—J. L. Lombardo. (*Electronics*, March 1956, Vol. 29, No. 3, pp. 168–170.) Description of the SAGE (semiautomatic ground environment) system, which does not depend on voice communication or interpretation of tracks by individual operators. Computers are used to identify unknown objects by correlating radar tracks with flight plans.

621.396.96: 551.578.1 **1729**

**A Turnstile Polarizer for Rain Cancellation.**—P. A. Crandell. (*Trans. Inst. Radio Engrs*, Jan. 1955, Vol. MTT-3, No. 1, pp. 10–15.)

621.396.963: 628.972 **1730**

**A Method of increasing the Ambient Illumination of Radar Operations Rooms without Reduction of Signal Detection Threshold.**—C. R. Barnard. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 199–202.) A narrow-band optical filter is arranged on the face of the display c.r. tube, and the colour of the illumination is chosen to be complementary to the response of the tube

621.396.969: 621.396.67 **1731**

**Reflection of Electromagnetic Waves from Thin Metal Strips (Passive Antennae).**—K. Lindroth. (*Kungl. tek. Högsk. Handl., Stockholm*, 1955, No. 91, 62 pp.) The accuracies of several previously described methods of calculating the current in the strips are compared.

621.396.969.32 **1732**

**Microwave Vehicle-Speed Indicator.**—G. W. G. Court. (*Wireless Engr*, March 1956, Vol. 33, No. 3, pp. 66–74.) A Doppler-radar-type instrument developed at the New Zealand Dominion Physical Laboratory uses a hybrid waveguide junction to provide both transmitting and receiving channels, so that only a single aerial is required. Leakage from the klystron oscillator used as c.w. transmitter provides local-oscillator power for the homodyne detector. Ranges of several hundred yards are obtained on small cars. An estimate of the various possible errors is included.

## MATERIALS AND SUBSIDIARY TECHNIQUES

533.583: 539.16 **1733**

**Use of Krypton-85 in measuring Gas Clean-Up Rates.**—D. J. Harris & P. O. Hawkins. (*Nature, Lond.*, 11th Feb. 1956, Vol. 177, No. 4502, pp. 285–286.) Techniques for monitoring the clean-up rate in pre-t.r. valves are briefly described. Radioactive krypton is more suitable than argon or xenon because of its long half-life and readily detectable radiation.

535.37 + 535.215]: 537.311.33 **1734**

**Cadmium Sulfide with Silver Activator.**—J. Lambe. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1586–1588.) Further experiments are reported, the results of which are consistent with the model for CdS(Ag) suggested previously [3274 of 1955 (Lambe & Klick)].



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535.37 : 546.472.21 **1735**

**X-Ray Powder Diffraction Data for Hexagonal Zinc Sulphide.**—M. A. Short & E. G. Steward. (*Acta cryst.*, 10th Nov. 1955, Vol. 8, Part 11, pp. 733–734.)

535.376 : 546.472.21 **1736**

**Electroluminescence in Disordered Zinc Sulphide.**—M. A. Short, E. G. Steward & T. B. Tomlinson. (*Nature, Lond.*, 4th Feb. 1956, Vol. 177, No. 4501, pp. 240–241.) Experiments are briefly reported indicating that electroluminescence both in single crystals and in powders of Cu-activated ZnS may be associated with one-dimensional structural disorder.

537.226/.227 **1737**

**Replacement of Ti in $BaTiO_3$ Ceramic by Si and Ge.**—K. W. Plessner & R. West. (*Proc. phys. Soc.*, 1st Dec. 1955, Vol. 68, No. 432B, pp. 1150–1152.) Permittivity/temperature curves are shown for $BaTiO_3$, $Ba(Ti_{0.9}Ge_{0.1})O_3$ and $Ba(Ti_{0.9}Si_{0.1})O_3$; the principal effect of introducing the Ge and Si is to reduce the peaks at the transitions at 120° and 10°C. Values of remanent polarization, coercive field and total permittivity are tabulated.

537.226/.227 **1738**

**Very-Low-Temperature Study of the Dielectric Constant of Ferroelectric Alkaline Phosphates and Arsenates.**—S. Le Montagner, J. Le Bot, M. Hagene, F. Lasbleis & M. Le Page. (*C. R. Acad. Sci., Paris*, 23rd Jan. 1956, Vol. 242, No. 4, pp. 475–478.) Anomalous variations corresponding to absorption maxima in the complex-dielectric-constant/temperature curves have been observed in the region of 60°–70°K at frequencies between 100 c/s and 1 Mc/s. Variation of the coercive force may be responsible for the effect, which is observed only in the ferroelectric phosphates and arsenates, i.e. those of K, Rb and Cs.

537.226 **1739**

**Dielectric Absorption in Dilute, Liquid, Polar Solutions: a New Approach.**—A. Fairweather. (*Proc. phys. Soc.*, 1st Dec. 1955, Vol. 68, No. 432B, pp. 1038–1042.) On the assumption that energy loss in a liquid polar dielectric is related to density rather than to viscosity, the relaxation time is shown to be proportional to $(a^5\rho/kT)^{\frac{1}{2}}$, where $a$ is the molecular radius, $\rho$ the density, $k$ Boltzmann's constant and $T$ the absolute temperature.

537.226 : 621.315.612.4 : 546.431.824-31 **1740**

**Dependence of the Dielectric Properties of Ceramic $BaTiO_3$ for High-Frequency Currents on the Technology of the Preparation of Samples.**—M. Jeżewski & T. Piech. (*Acta phys. polon.*, 1955, Vol. 14, No. 5, pp. 395–405.) Measurements were made on a series of samples prepared by grinding, pressing and re-sintering the previously prepared sample. The dielectric constant increases significantly with the amount of processing; the losses do not vary significantly.

537.226.2/.3 : 621.317.3.029.6 **1741**

**Measurements of the Dielectric Constant and Loss Angle of Building Materials.**—M. Balachandran. (*Z. angew. Phys.*, Dec. 1955, Vol. 7, No. 12, pp. 588–593.) Measurements were made on brick, gypsum, cement and various wood specimens at 10 cm $\lambda$, and on oak and beech also at 8·75 and 3·2 cm $\lambda$. The effects of water absorption are shown graphically.

537.227/.228 : 546.431.824-31 **1742**

**Theory of Spontaneous** [ferroelectric] **Deformation of Barium Titanate.**—W. Kinase & H. Takahashi. (*J. phys. Soc. Japan*, Nov. 1955, Vol. 10, No. 11, pp. 942–952.)

537.227/.228.1 : 547.476.3 **1743**

**Electrical After-Effects in Rochelle Salt.**—K. N. Karmen. (*Zh. eksp. teor. Fiz.*, Oct. 1955, Vol. 29, No. 4 (10), pp. 533–534.) The observed changes of the charge/discharge characteristics following application of a pulsed electric field for various lengths of time are presented graphically and briefly discussed.

537.227 : [546.32.882.5 + 546.33.882.5 **1744**

**A Thermodynamic Treatment of Ferroelectricity and Antiferroelectricity in Pseudo-cubic Dielectrics.**—L. E. Cross. (*Phil. Mag.*, Jan. 1956, Vol. 1, No. 1, pp. 76–92.) "The Kittel-Devonshire phenomenological treatment of antiferroelectricity is extended to the case of polarizations in three dimensions in a pseudo-cubic material. There are ten possible solutions of the proposed free energy equation, corresponding to non-polar, ferroelectric, antiferroelectric and ferrielectric states, and expressions are derived for the polarization and dielectric stiffness coefficients in these forms." The theory is applied to $NaNbO_3$ and $KNbO_3$ and their solid solution $(NaK)NbO_3$.

537.227 : 546.431.824-31 **1745**

**Dynamic Method for measuring the Pyroelectric Effect with Special Reference to Barium Titanate.**—A. G. Chynoweth. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 78–84.) "Transient currents produced in single crystals of barium titanate when subjected to flashes of light are shown to be pyroelectric in origin. The illumination results in a small change in the temperature of the crystal which, in turn, causes the polarization to change. This change is recorded as a current in the external circuit. It is shown that from room temperature up to the Curie point, the pyroelectric current is consistent with the polarization as a function of temperature, as determined from hysteresis loop measurements. The technique proves to be a sensitive and nondestructive method for studying the state of polarization of a crystal. The technique is used to study the pyroelectric effect induced by applied static electric fields at temperatures above the Curie point. The results are consistent with Devonshire's theory of the ferroelectricity of $BaTiO_3$, and they confirm that the Curie point transition is of the first order."

537.311.33 **1746**

**The Concept of the Hole in Semiconductors.**—J. L. Salpeter. (*Proc. Instn Radio Engrs, Aust.*, Dec. 1955, Vol. 16, No. 12, pp. 427–442.) Use is made of the transmission-line and wave-filter analogy to explain the concept of the hole. The behaviour of semiconductors subjected to magnetic fields and mechanical forces and the thermoelectric power of semiconductors are discussed.

537.311.33 **1747**

**Magnetic Susceptibility of Impurity-Trapped Electrons and Holes in Semiconductors.**—E. Mooser. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1589–1592.) Calculations are made explicitly for donor impurities; similar reasoning holds for acceptors. At low temperatures there is an appreciable difference between the values of susceptibility of the electron gas with and without the impurities; this difference enables the presence of an impurity conduction band to be determined from magnetic measurements. Measurements on Si reported by Portis et al. (3342 of 1953) are interpreted in terms of the theory. A narrow donor band is found in Si containing $1 \cdot 5 \times 10^{18}$ P atoms/cm³, in agreement with Baltensperger's predictions (1451 of 1954).



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537.311.33 1748

**Impurity Band in Semiconductors with Small Effective Mass.**—F. Stern & R. M. Talley. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1638–1643.) An approximate calculation of the energy states for the 1*s* band of metallic hydrogen is carried out for lattice constants smaller than those considered by Baltensperger (1451 of 1954). A simple transformation of the distance and energy scales makes the calculation applicable to impurities in a semiconductor. Optical measurements of the energy gap in InAs as a function of impurity content are reported. The effective carrier mass required to fit published optical data for InSb is about 0·03 *m*, as compared with 0·013 *m* found by cyclotron-resonance measurements.

537.311.33 1749

**Interaction of Impurities and Mobile Carriers in Semiconductors.**—G. W. Lehman & H. M. James. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1698–1712.) A comprehensive analysis is presented. The theory differs from others in predicting a marked temperature dependence of the activation energy; this results from the temperature dependence of the polarizability of the mobile carrier distribution.

537.311.33 1750

**A Particular Form of the Equations governing the Propagation of Free Carriers in a Homogeneous Crystal Lattice of Junction Type in a Unidimensional System.**—A. Leblond. (*C. R. Acad. Sci., Paris*, 4th Jan. 1956, Vol. 242, No. 1, pp. 85–87.) Analysis is given for a semiconductor system comprising a number of parallel plane junctions. Equations permitting of solution by simple numerical integration are derived by choosing as unknown variables the numbers of free electrons and holes and the electric field strength; $I/V$ characteristics can hence be deduced.

537.311.33 1751

**Properties and Structures of Ternary Semiconducting Systems: Part 1.**—B. T. Kolomiets & N. A. Goryunova. (*Zh. tekh. Fiz.*, June 1955, Vol. 25, No. 6, pp. 984–994.) An experimental investigation has shown that in the pseudo-binary section $m\mathrm{Tl_2Se}.n\mathrm{Sb_2Se_3}$ of the ternary system Tl-Sb-Se there is a compound $Tl_2Sb_2Se_4$ which is a typical *p*-type semiconductor. By altering the proportion of the constituents in the series $m\mathrm{Tl_2Se}.n\mathrm{Sb_2Se_3}$ it is possible to obtain a large variety of semiconductors. Replacement of Sb by As in the system gives a new group of semiconductors of amorphous structure. It is suggested that a study of ternary systems should lead to the discovery of semiconductors with new basic properties.

537.311.33 1752

**Bipolar Diffusion in Semiconductors at Heavy Currents.**—K. B. Tolpygo & I. G. Zaslavskaya. (*Zh. tekh. Fiz.*, June 1955, Vol. 25, No. 6, pp. 955–977.) A solution is given of equations describing bipolar diffusion in a semiconductor in which there is an inversion of the sign of conductivity. The forward current is considered for a plane or hemispherical contact; in addition to 'flooding' of the barrier layer by current carriers, the penetration of carriers of one sign into the region of opposite sign is of great importance. As a result, the total resistance of the system is much lower than that of a homogeneous semiconductor of the same thickness. Calculated voltage/current characteristics for forward current are plotted.

537.311.33 1753

**Electrical Properties of the Intermetallic Compounds $Mg_2Si$, $Mg_2Ge$, $Mg_2Sn$ and $Mg_2Pb$.**—U. Winkler. (*Helv. phys. Acta*, 15th Dec. 1955, Vol. 28, No. 7, pp. 633–666. In German.) Polycrystalline specimens were prepared by direct co-fusion of the ingredients. Measurements of conductivity, Hall constant and thermoelectric power over the temperature range 100°–1 100°K indicate that the compounds are true semiconductors; $Mg_2Pb$ appears to be strongly degenerate.

537.311.33: 535.215: 546.289 1754

**Negative Photoeffects in Semiconductors.**—F. Stöckmann. (*Z. Phys.*, 12th Dec. 1955, Vol. 143, No. 3, pp. 348–356.) The observed decrease of conductivity on illuminating a Ge specimen which had previously been bombarded by fast electrons is discussed. This effect is due to the removal of minority carriers from impurity centres and their recombination with the majority carriers. The effect occurs most easily in semiconductors with doubly charged impurities in the lattice. A full account of the investigation is to be published in *Phys. Rev.*

537.311.33: 536.2 1755

**A New Method of measuring the Thermal Characteristics of Semiconductors.**—M. A. Chernyakova & A. F. Chudnovski. (*Zh. tekh. Fiz.*, June 1955, Vol. 25, No. 6, pp. 1013–1018.) A single arrangement, based on a bridge circuit, is used to determine electrical conductivity $\sigma$, thermal conductivity $\lambda$, volume thermal capacity $C$, thermometric conductivity $\lambda/C$ and thermal admittance $\sqrt{\lambda C}$. The method is based on certain regularities of a nonstationary temperature field during the cooling (or heating) of a body; it is particularly convenient for obtaining thermal characteristics of thermistors.

537.311.33: 538.63 1756

**Experimental Investigation of Transverse Nernst-Ettingshausen Effect in Tellurium.**—I. V. Mochan. (*Zh. tekh. Fiz.*, June 1955, Vol. 25, No. 6, pp. 1003–1012.)

537.311.33: 538.632 1757

**Theory of Hall Effect in Ionic Semiconductors.**—M. I. Klinger. (*Zh. eksp. teor. Fiz.*, Oct. 1955, Vol. 29, No. 4 (10), pp. 439–448.) The Hall constant of ionic semiconductors is calculated using the method of steady states. The interaction between an electron and the polarization oscillations of the crystal is considered in the adiabatic and the weak-coupling approximations.

537.311.33: [546.28 + 546.289 1758

**A Mathematical Analysis of Solute Redistribution during Solidification.**—V. G. Smith, W. A. Tiller & J. W. Rutter. (*Canad. J. Phys.*, Dec. 1955, Vol. 33, No. 12, pp. 723–745.) It is shown and experimentally verified that *p-n* junctions may be produced during solidification in Ge and Si melts containing two suitable solutes, e.g. Ga and Sb in Ge.

537.311.33: [546.28 + 546.289 1759

**Statistics and Galvanomagnetic Effects in Germanium and Silicon with Warped Energy Surfaces.**—B. Lax & J. G. Mavroides. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1650–1657.) Calculations based on the Boltzmann transport theory are applied to the warped energy surfaces which have been determined by cyclotron-resonance experiments. Expressions are derived for the hole densities, conductivity, effective carrier masses, intrinsic carrier concentration and Hall coefficient as a series expansion in terms of the anisotropy parameters of the warped surfaces.





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537.311.33: 546.28 **1760**

**Exchange Effects in Spin Resonance of Impurity Atoms in Silicon.**—G. Feher, R. C. Fletcher & E. A. Gere. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1784–1786.) Observations lending support to Slichter's theory (151 of January) are reported.

537.311.33: 546.289 **1761**

**Observations of Dislocations along Grain Boundaries in Germanium Crystals.**—J. Okada. (*J. phys. Soc. Japan*, Nov. 1955, Vol. 10, No. 11, pp. 1018–1019).

537.311.33: 546.289 **1762**

**On the Coupled Dislocations along a Grain Boundary.**—Y. Uemura. (*J. phys. Soc. Japan*, Nov. 1955, Vol. 10, No. 11, pp. 1020–1022.) Theoretical calculations are presented relevant to the observations of Okada (1761 above) and Oberly (745 of 1955).

537.311.33: 546.289 **1763**

**Amphoteric Impurity Action in Germanium.**—W. C. Dunlap, Jr. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1629–1633.) Impurities capable of acting either as donors or acceptors are discussed, gold being taken as an example; the effect depends on the presence of other impurities. The existence of a donor level at 0·05 eV above the valance band as well as two acceptor levels at 0·15 and 0·55 eV is confirmed.

537.311.33: 546.289 **1764**

**Carrier Capture Probabilities in Nickel-Doped Germanium.**—J. F. Battey & R. M. Baum. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1634–1637.) "Nickel has been diffused into germanium in order to study the carrier capture probabilities of the two nickel acceptor levels. Measurements of minority carrier lifetime as a function of temperature show that the electron capture probability of low-resistivity *p*-type samples is temperature-independent. The electron capture probability of high-resistivity *p*-type samples increases exponentially with increasing temperature, as does the hole capture probability of high-resistivity *n*-type samples. Possible interpretations of the results are discussed."

537.311.33: 546.289 **1765**

**Thermal Acceptors in Vacuum Heat-Treated Germanium.**—R. L. Hopkins & E. N. Clarke. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1786–1787.) An experiment is described which indicates that very few acceptor centres are introduced into Cu-free Ge by quenching from high temperatures provided care is taken to maintain the Ge surface free from impurities.

537.311.33: 546.289 **1766**

**Investigations of Surface Recombination Velocities on Germanium by the Photoelectromagnetic Method.**—T. M. Buck & W. H. Brattain. (*J. electrochem. Soc.*, Nov. 1955, Vol. 102, No. 11, pp. 636–640.) Ge specimens subjected to various surface treatments and to temperatures between 65° and 100°C were investigated using technique described by Moss et al. (748 of 1954). Results indicate that the method does not permit accurate calculation of surface recombination velocity.

537.311.33: 546.289 **1767**

**Surface States on Germanium.**—J. Lees & S. Walton. (*Proc. phys. Soc.*, 1st Dec. 1955, Vol. 68, No. 432B, pp. 1152–1153.) *I*/*V* characteristics of W contacts on *p*- and *n*-type Ge specimens with a range of resistivities are presented. The results are in agreement with Bardeen's surface-states theory (*Phys. Rev.*, 15th May 1947, Vol. 71, No. 10, pp. 717–727).

537.311.33: 546.289 **1768**

**Modulation of the Surface Conductance of Germanium by Pulsed Electric Fields.**—G. G. E. Low. (*Proc. phys. Soc.*, 1st Dec. 1955, Vol. 68, No. 432B, pp. 1154–1157.) The effect found previously (2007 of 1955), that the free surface of *n*-type Ge is positive with respect to the bulk of the material in the presence of a pulsed negative field, is confirmed; it is explained as a capacitance effect resulting from the action of surface traps.

537.311.33: 546.561-31 **1769**

**Exciton Absorption in Cuprous Oxide.**—J. H. Apfel & L. N. Hadley. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1689–1691.)

537.311.33: 546.681.86 **1770**

**Fast-Neutron Bombardment of GaSb.**—J. W. Cleland & J. H. Crawford, Jr. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1614–1618.) Experimental results indicate that the charge-carrier concentration and mobility of *n*- and *p*-type GaSb decrease as a consequence of neutron bombardment. Effects obtainable by heat treatment subsequent to the bombardment are discussed.

537.311.33: 546.682.19 **1771**

**Pressure Dependence of the Resistivity, Hall Coefficient, and Energy Gap for InAs.**—J. H. Taylor. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1593–1595.) Measurements have been made at pressures from 1 to 2 000 atm. Both resistivity and Hall constant increase exponentially over the range, the total resistivity increase being 19% and the total Hall-constant increase being 12% at 201°C. The pressure coefficient of energy gap is deduced from the resistivity variation to be $8{\cdot}8 \times 10^{-6}$ eV/atm, and from the Hall-constant variation to be $5{\cdot}5 \times 10^{-6}$ eV/atm; the latter value is considered the more accurate.

537.311.33: 546.682.86 **1772**

**Hall Effect and Conductivity of InSb.**—H. J. Hrostowski, F. J. Morin, T. H. Geballe & G. H. Wheatley. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1672–1676.) The conductivity and Hall coefficient of high-purity single-crystal specimens of InSb have been measured over the temperature range 1·3°–700°K; semiconductor properties of the material are deduced.

537.311.33: 546.682.86 **1773**

**The Lifetime of Added Carriers in InSb.**—I. M. Mackintosh & J. W. Allen (*Proc. phys. Soc.*, 1st Dec. 1955, Vol. 68, No. 432B, pp. 985–990.) Experimental optical-absorption curves of *n*-type and *p*-type samples of InSb are analysed on the basis of the Roosbroeck-Shockley theory of radiative recombination (3258 of 1954), allowance being made for degeneracy. A decay time of 0·75 μs is indicated for a small disturbance in carrier concentration. The results suggest that the radiative process may be the predominant recombination mechanism in this material.

537.311.33: 546.682.86 **1774**

**Melting Patterns appearing on Single Crystals of InSb.**—M. F. Millea & C. T. Tomizuka. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 96–97.)

537.311.33: 669.046.54 **1775**

**Electromagnetic Suspension of a Molten Zone.**—W. G. Pfann & D. W. Hagelbarger. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 12–18.) A zone-melting method requiring no container is described. A rod of



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the material is held horizontally, clamped at both ends, and a direct current is passed through it. At the region where melting is to be effected a horizontal magnetic field is applied normal to the rod. The resulting vertical force on the rod balances the gravitational pull. Various applications are indicated, including the production of semiconductor junctions by the remelt or the rate-growing process.

537.311.62: 546.811 **1776**

**Surface Resistance of Tin in Superconducting State at a Frequency of 7·3 × $10^{10}$ c/s.**—P. A. Bezuglyi, A. A. Galkin & G. Ya. Levin. (*C. R. Acad. Sci. U.R.S.S.*, 1st Dec. 1955, Vol. 105, No. 4, pp. 683–684. In Russian.)

537.312.8: 538.639: 546.3-1-74-72 **1777**

**Electrical Resistance of Iron-Nickel Alloys at Low Temperatures (14°–90°K) and its Change in a Strong Magnetic Field.**—E. Kondorski & I. Ozhigov. (*C. R. Acad. Sci. U.R.S.S.*, 21st Dec. 1955, Vol. 105, No. 6, pp. 1200–1203. In Russian.) An experimental investigation of alloys containing between 40% and 100% Ni. The effect of heat treatment was also investigated. Results are presented graphically.

537.533: 537.311.33 **1778**

**Electron Bombardment Effects in Thin Dielectric Layers.**—W. E. Spear. (*Proc. phys. Soc.*, 1st Dec. 1955, Vol. 68, No. 432B, pp. 991–1000.) An investigation of primary- and secondary-electron currents is described for layers between 0·7 and 5 μ thick, of mica, pyrex, $As_2S_3$ and $Sb_2S_3$, using bombarding electron energies up to 50 keV and, in the case of mica, with fields up to $10^6$ V/cm across the specimen. The values of primary and secondary currents for specimens of different thickness and material fall on common curves when plotted against a suitable independent variable. The secondary-current curves are interpreted in terms of the displacement of charge carriers in the space-charge field within the dielectric.

538.1: 538.221 **1779**

**Theory of Atomic Magnetic Moments in Ferromagnetic Materials.**—N. S. Akulov. (*C. R. Acad. Sci. U.R.S.S.*, 11th Dec. 1955, Vol. 105, No. 5, pp. 935–938. In Russian.) Simple formulae are derived for elements and alloys, on the basis of the zone theory.

538.221 **1780**

**Ferromagnetic Domains in Permanent Magnet Materials.**—L. F. Bates. (*Research, Lond.*, Dec. 1955, Vol. 8, No. 12, pp. 462–472.) A general account is given of the domain concept and its application to ferromagnetic metals. Quantitative tests of contemporary theories by means of powder-pattern technique are described. Photographs and diagrams of powder patterns on alnico, columnar alcomax and other materials are reproduced.

538.221 **1781**

**Technical Properties of Iron Powder Magnets.**—E. H. Carman. (*Brit. J. appl. Phys.*, Dec. 1955, Vol. 6, No. 12, pp. 426–429.) The coercive force, remanence and maximum energy product of compacts of iron prepared by hydrogen reduction of ferric oxide were measured as functions of the density of packing and the particle size. The results are presented graphically. The presence of a small percentage of oxide does not appreciably affect the quality of the magnets.

538.221 **1782**

**Influence of Magnetic Field on the Precipitation Process of Ferromagnetic Phase in Cu-Co Alloy.**—T. Mitui & S. Miyahara. (*J. phys. Soc. Japan*, Nov. 1955, Vol. 10, No. 11, pp. 1023–1024.)

538.221: 534.121.1 **1783**

**[Mechanical] Damping in Iron-Nickel Alloys.**—R. Ochsenfeld. (*Z. Phys.*, 12th Dec. 1955, Vol. 143, No. 3, pp. 357–373.) Apparatus for measuring the damping of flexural vibrations of the alloy strips is described. The vibrations, produced magnetically, were at frequencies between 200 and 1 300 c/s. Results of measurements are discussed and compared with theoretical results; the contributions from magnetic and magnetomechanical hysteresis and from macroscopic and microscopic eddy currents are identified.

538.221: 538.632 **1784**

**Hall Effect, Spontaneous Magnetization and Temperature.**—E. A. Ascher. (*Helv. phys. Acta*, 15th Dec. 1955, Vol. 28, No. 7, pp. 667–693. In French, with English summary.) Hall effect in ferromagnetic materials is studied on the basis of theory of spontaneous effects; a law is derived relating the spontaneous Hall effect to the spontaneous magnetization at a given temperature. Irreversible Fe-Ni alloys are used to permit the spontaneous magnetization to be varied without changing the temperature of the sample. See also 2337 of 1955 (Perrier & Ascher).

538.221: 538.65 **1785**

**The Magneto-elastic Properties of some Ferromagnetic Iron-Nickel Alloys.**—R. Ochsenfeld. (*Z. Phys.*, 22nd Dec. 1955, Vol. 143, No. 4, pp. 375–391.) An investigation of changes in elastic modulus with magnetization ($\Delta E$ effect) and with amplitude of vibration ($\delta E$ effect) for 36% and 60% Ni strips. See also 1783 above.

538.221: 538.652: 546.74 **1786**

**Residual Magnetization and Magnetostriction of Nickel Single Crystals.**—Y. Nakamura. (*J. phys. Soc. Japan*, Nov. 1955, Vol. 10, No. 11, pp. 937–941.) A report of measurements made on long cylindrical crystals at room temperature.

538.221: 546.666 **1787**

**Magnetic Properties of Erbium Metal.**—J. F. Elliott, S. Legvold & F. H. Spedding. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1595–1596.) Measurements indicate that the material becomes ferromagnetic at a temperature near 20°K.

538.221: 621.318.124 **1788**

**Mechanism by which Cobalt Ferrite heat-treats in a Magnetic Field.**—H. J. Williams, R. D. Heidenreich & E. A. Nesbitt. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 85–89.) Magnetic torque measurements and electron-diffraction observations on several Co and CoZn ferrites, interpreted in the light of previous work on $Fe_2NiAl$ and alnico 5 [see e.g. 172 of 1955 (Nesbitt et al.)], show that correlation between torque reversals and response to heat treatment in a magnetic field indicates the presence of fine precipitated particles of a second phase in the composition of the material.

538.221: 621.318.134 **1789**

**Paramagnetism of some Rare-Earth Ferrites.**—J. C. Barbier & R. Aléonard. (*C. R. Acad. Sci., Paris*, 4th Jan. 1956, Vol. 242, No. 1, pp. 83–85.) Continuation of the investigation reported by Benoit (3319 of 1955).

538.221: 621.318.134 **1790**

**Structure of Rare-Earth Ferrimagnetic Ferrites.**—F. Bertaut & F. Forrat. (*C. R. Acad. Sci., Paris*, 16th Jan. 1956, Vol. 242, No. 3, pp. 382–384.) Discussion indicates that the spontaneous magnetization exhibited by these ferrites could not result from a



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perovskite structure but is consistent with a composition $Fe_5B_3O_{12}$ (B representing the rare earth) having the two-sublattice structure proposed by Néel (3275 of 1954).

538.221 : 621.318.134 : 538.569.4 **1791**

**Ferromagnetic Resonance in Manganese Ferrite Single Crystals.**—P. E. Tannenwald. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1713–1719.) Two types of Mn ferrite were investigated at temperatures ranging from 4·2° to 300°K, using frequencies of 24, 9·1, 5·6, and 2·8 kMc/s. Resonance lines as narrow as 47 oersted were obtained; the width depends on crystal orientation, temperature and frequency. The anisotropy does not depend on frequency but increases rapidly at low temperature. Double resonances have been observed.

538.221 : 621.318.134 : 538.614 **1792**

**Study of Magnetic Rotatory Polarization in Copper Ferrite at 10 kMc/s.**—F. Mayer. (*C. R. Acad. Sci., Paris*, 4th Jan. 1956, Vol. 242, No. 1, pp. 81–83.) Measurements of the Faraday rotation are used to study the different properties of the cubic and quadratic crystal forms of Cu ferrite. The polarization-rotation-angle/magnetic-field characteristics are loops resembling the usual magnetization curves. Losses on introducing the two specimens in a waveguide are field-independent for the cubic form. Investigations of the polarization ellipticity indicate that the cubic form produces selective absorption.

538.221 : 621.385.833 **1793**

**Depiction of Domains of a Ferromagnetic Material by an Electron-Optical Method.**—G. V. Spivak, N. G. Kanavina, I. S. Sbitnikova & T. N. Dombrovskaya. (*C. R. Acad. Sci. U.R.S.S.*, 1st Dec. 1955, Vol. 105, No. 4, pp. 706–708. In Russian.) Photographs of images (× 50) obtained by the secondary-emission-microscope method [2739 of 1954 (Spivak et al.)] and by the powder-pattern method are compared.

538.221 : 621.385.833 **1794**

**Magnetic Contrast in Electronic Mirrors and Observation of Domains in a Ferromagnetic Material.**—G. V. Spivak, I. N. Prilezhaeva & V. K. Azovtsev. (*C. R. Acad. Sci. U.R.S.S.*, 11th Dec. 1955, Vol. 105, No. 5, pp. 965–967. In Russian.) Further development of earlier work (1793 above) is reported. Microphotographs (× 150) of electron-optical images of domain structures are shown.

538.569.3 : 621.372.56.029.63/.64 **1795**

**R.F. Attenuators and Load Materials.**—Lichtman. (See 1647.)

546.3-1 : 541.57 **1796**

**Covalent Alloys among the Intermetallic Compounds. The Compounds PrGe and CaGe.**—A. Iandelli. (*R. C. Accad. naz. Lincei*, Nov. 1955, Vol. 19, No. 5, pp. 307–313.)

621.319.2 **1797**

**The Mechanism of some Electrets.**—K. Antenen. (*Z. angew. Math. Phys.*, 25th Nov. 1955, Vol. 6, No. 6, pp. 478–484.) Measurements were made on carnauba-wax disks with thin silver electrodes on the faces and potential probes sealed at points round the circumference. The potential distribution through the disk was determined at temperatures of 35°, 50° and 70°C. Charging and discharge currents exhibited the expected time variation. The results indicate that the electret effect in carnauba wax is due to the low conductivity of ions in the electric field.

## MATHEMATICS

517 **1798**

**Laplace Transformation.**—H. Goldenberg. (*Elect. Rev., Lond.*, 23rd Dec. 1955, Vol. 157, No. 26, pp. 1223–1224.) An elementary explanation of the Laplace transformation is given and illustrated by examples. The use of tables of Laplace transforms to find Heaviside pairs not easily obtainable by Heaviside calculus is demonstrated.

517 : 512.831 **1799**

**The Solution of Linear Simultaneous Equations by Matrix Iteration.**—J. Guest. (*Aust. J. Phys.*, Dec. 1955, Vol. 8, No. 4, pp. 425–439.)

517.43 **1800**

**Mikusiński's Operational Calculus.**—V. Dolezal & J. Kurzweil. (*Slab. Obz., Prague*, Nov. 1955, Vol. 16, No. 11, pp. 582–592.) An introductory article which includes the fundamental theory of the calculus, its relation to the Laplace transform and examples of its applications in circuit theory and the solution of ordinary differential equations with constant coefficients. The calculus is applicable in several cases where the Laplace transform method fails.

517.94 : [535.13 + 538.561 **1801**

**On Cauchy's Problem for Hyperbolic Equations and the Differentiability of Solutions of Elliptic Equations.**—P. D. Lax. (*Commun. pure appl. Math.*, Nov. 1955, Vol. 8, No. 4, pp. 615–633.) The Cauchy problem for symmetric hyperbolic systems of the first order is discussed; the class includes all equations in physics describing reversible time-dependent phenomena including Maxwell's equations, the equations of magnetohydrodynamics, etc. A theorem is presented on the differentiability of weak solutions of an elliptic equation of order $2m$.

517.948.3 **1802**

**A New Method for solving Fredholm Integral Equations.**—C. Müller. (*Commun. pure appl. Math.*, Nov. 1955, Vol. 8, No. 4, pp. 635–640.)

519.283 **1803**

**Statistical Techniques for reducing the Experiment Time in Reliability Studies.**—M. Sobel. (*Bell Syst. tech. J.*, Jan. 1956, Vol. 35, No. 1, pp. 179–202.)

## MEASUREMENTS AND TEST GEAR

535.24 : 535.37 **1804**

**Direct Measurement of Quantity of Light in Rapidly Decaying Luminescence Processes.**—N. A. Tolstoi & I. A. Litvinenko. (*Zh. eksp. teor. Fiz.*, Oct. 1955, Vol. 29, No. 4 (10), pp. 507–515.) An instrument for measuring the time integral of the light-quantum output in the rise and the decay of luminescence is described; circuit and block diagrams are given. The processes investigated have equivalent exponential-curve time-constants between $10^{-5}$ and $10^{-1}$ sec.

621.3 : 621.319.4 : 537.523.3 **1805**

**The Detection of Corona Discharges in High-Voltage Air Capacitors.**—L. Medina. (*Aust. J. appl. Sci.*, Dec. 1955, Vol. 6, No. 4, pp. 453–457.) Corona discharge giving rise to increased power factor in capacitors used in a.c. bridges etc. may be detected by measurement of the direct component produced in the current through the capacitor.



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621.3.018.4(083.74): 621.385.029.6 **1806**

**A Method of forming a Broad-Band Microwave Frequency Spectrum.**—R. E. Wall, Jr, & A. E. Harrison. (*Trans. Inst. Radio Engrs*, Jan. 1955, Vol. MTT-3, No. 1, pp. 4–10.) The beam-accelerating voltage of a klystron is modulated by two h.f. voltages, one frequency being an integral multiple of the other; the sidebands so produced are suitable for use as microwave frequency standards.

621.317: 621.383.2 **1807**

**The Photodianode: Modulation of the Differential Current by an Alternating Magnetic Field.**—Deloffre, Pierre & Roig. (See 1895.)

621.317.3: 621.374.3: 621.372.8 **1808**

**Waveguide Investigations with Millimicrosecond Pulses.**—A. C. Beck. (*Bell Syst. tech. J.*, Jan. 1956, Vol. 35, No. 1, pp. 35–65.) Equipment for the generation, reception and display of 5-mμs pulses is described. Dominant-mode and multi-mode waveguide applications are considered. Resolution tests show the practicability with this technique of separating radar targets 4 ft apart. Pulses 70 dB below the level of the outgoing pulse can be observed.

621.317.3: 621.385.832.001.4 **1809**

**Testing Cathode-Ray Tubes.**—Nixon. (See 1919.)

621.317.3: 621.397.6 **1810**

**State of Standardization of Test and Measurement Methods for Television Transmission Technique.**—Müller. (See 1879.)

621.317.32: 621.396.61 **1811**

**A Method for the Direct Measurement of Spurious Emissions.**—S. Kurokawa, T. Takahashi & M. Arai. (*J. Radio Res. Labs, Japan*, July 1955, Vol. 2, No. 9, pp. 217–220.) Measurements in the frequency band 30–200 Mc/s are effected by use of a directional coupler to connect a screened selective receiver and output meter to the feed line from the transmitter.

621.317.326: 621.385.2 + 621.397.62 **1812**

**The Response of Diode Circuits to Periodic Pulses.**—Suhrmann. (See 1883.)

621.317.33: 621.384.622 **1813**

**The Shunt Resistance of Linear Accelerators.**—W. Chahid. (*C. R. Acad. Sci., Paris*, 9th Jan. 1956, Vol. 242, No. 2, pp. 244–247.) Application of the method of measuring cavity-resonator shunt resistance described previously (1324 of May). Results are compared with those obtained by the methods of Denis & Liot (1076 of 1948) and of Hall & Parzen (799 of 1954).

621.317.335 **1814**

**Cell with Fixed Electrodes for Measurement of the Dielectric Constant of a Liquid.**—C. Abgrall. (*C. R. Acad. Sci., Paris*, 4th Jan. 1956, Vol. 242, No. 1, pp. 76–78.) Details are given of the construction of a cell for use in the method described previously (1132 of 1954).

621.317.335.3.029.64 **1815**

**The Measurement of Small Changes in Dielectric Constant by means of a Cavity Wavemeter.**—E. S. Hotston & J. E. Houldin. (*J. sci. Instrum.*, Dec. 1955, Vol. 32, No. 12, pp. 484–485.) A modification of a cylindrical $H_{01n}$ cavity-resonator design allows the dielectric constant to be determined from measurements including the length of the air-filled part of the resonator instead of the usual observation of the change of length of the resonator on insertion of the dielectric. At frequencies of about 9·6 kMc/s values obtained for dielectric constants of glass disks 0·08 in. thick were consistent to within 1 part in 750.

621.317.4: 621.318.2 **1816**

**Precision Apparatus for Investigations of Aging in Permanent Magnets.**—R. K. Tenzer. (*Arch. tech. Messen*, Dec. 1955, No. 239, pp. 285–288.) Apparatus developed in connection with the investigations described by Kronenberg (772 of 1954) is designed for ballistic measurements of induction using a compensation principle; the voltage pulse induced in the test coil when it is withdrawn from the permanent magnet is balanced against a pulse of known amplitude.

621.317.42.082.72 **1817**

**A New Magnetic Flux Probe.**—J. E. Parton & G. D. Stairmand. (*J. sci. Instrum.*, Dec. 1955, Vol. 32, No. 12, pp. 464–467.) A differential-capacitance probe suitable for use in steady or transient fields of strength above 100 G is described. It comprises three parallel members, the middle one of which is current-carrying. This member is deflected by the magnetic field so that its capacitance to the earthed outer members changes. The change is detected by means of a bridge circuit.

621.317.7 **1818**

**Electronic Measuring Instruments.**—E. H. W. Banner. (*Elect. Rev., Lond.*, 30th Dec. 1955, Vol. 157, No. 27, pp. 1264–1267.) The different classes of commercially available voltmeter and testing set are indicated, and an example of each is briefly described.

621.317.729 **1819**

**A Simple Equipment for solving Potential and other Field Problems.**—C. T. Murray & D. L. Hollway. (*J. sci. Instrum.*, Dec. 1955, Vol. 32, No. 12, pp. 481–483.) Two-dimensional field problems are solved by using, as an electrical analogue, current flow in a sheet of ordinary paper, where pencil lines mark the electrode boundaries. Details of the circuit and the construction of the equipment are given.

621.317.729 **1820**

**An Electrolytic-Tank Equipment for the Determination of Electron Trajectories, Potential and Gradient.**—D. L. Hollway. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 155–160. Discussion, pp. 163–165.) A description is given of equipment for testing either axially symmetric or two-dimensional systems; it can be switched to measure potential gradients, and to trace electron trajectories. The accuracy is sufficient for most problems of electrode design.

621.317.729: 538.691 **1821**

**A Method of tracing Electron Trajectories in Crossed Electric and Magnetic Fields.**—D. L. Hollway. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 161–163. Discussion, pp. 163–165.) An extension of Gabor's tangent method (*Nature, Lond.*, 27th Feb. 1937, Vol. 139, No. 3513, p. 373) is used. Comparison of results with calculated paths for a trochoid indicates that the accuracy is satisfactory, being almost equal to that in purely electric fields.

621.317.73.029.64 **1822**

**Automatic Plotter for Waveguide Impedance.**—H. L. Bachman. (*Electronics*, March 1956, Vol. 29, No. 3, pp. 184–187.) The input impedance of a waveguide component is automatically measured over the frequency range 8·5–9·6 kMc/s, the impedance locus in



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the reflection-coefficient plane being displayed on a c.r.o. screen. Comparison with slotted-line measurements indicates that the maximum errors in magnitude and phase of the reflection coefficient are 10% and 5° respectively, occurring at the ends of the frequency band. See also *Trans. Inst. Radio Engrs*, Jan. 1955, Vol. MTT-3, No. 1, pp. 22–30.

621.317.755 1823
**A Multi-trace Cathode-Ray-Tube Display.**—K. E. Wood & T. C. Keenan. (*Electronic Engng*, March 1956, Vol. 28, No. 337, pp. 105–107.) Equipment for displaying nine traces sequentially derives the switching waveform from a neon counter. Input frequencies up to 100 c/s can be displayed.

621.317.755 1824
**An Ultra-high-Speed Oscillograph.**—F. R. Connor. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 178–181.) The instrument described has a linear sweep speed of 2·5 cm/mμs, with a full scan of 5 cm, and incorporates a c.r. tube with small plate systems. The Y-plate system is designed as a transmission line which can be either resonant or nonresonant, thus providing for narrow-band or wide-band matching. A coaxial-cable delay unit is included, and a calibrating circuit provides a 1·25-kMc/s timing waveform.

621.317.755 1825
**Cathode-Ray Oscilloscope Intensity Modulator.**—R. F. Kemp. (*Rev. sci. Instrum.*, Dec. 1955, Vol. 26, No. 12, pp. 1120–1121.) A voltage derived by a push-pull differentiating amplifier from the vertical deflection signal is added to the brilliancy control voltage, thus preventing variation of trace brightness due to variation of writing speed.

621.317.755 1826
**Equipment for the Vectorial Display of Alternating Voltages in the Frequency Range 5–215 kc/s.**—E. C. Pyatt. (*J. sci. Instrum.*, Dec. 1955, Vol. 32, No. 12, pp. 469–471.) A c.r.o. giving an Argand-diagram display is described; applications to measurements on electromechanical devices are indicated.

621.317.76 1827
**Wavelength Measurement in the Millimeter Region.**—H. H. Theissing & J. McCue. (*Rev. sci. Instrum.*, Dec. 1955, Vol. 26, No. 12, pp. 1203–1204.) Outline description of an interferometer arrangement using two nearly parallel semitransparent metal films interposed between source and detector.

621.317.761 1828
**Electronic Device for measuring Reciprocal Time Intervals.**—E. F. MacNichol, Jr, & J. A. H. Jacobs. (*Rev. sci. Instrum.*, Dec. 1955, Vol. 26, No. 12, pp. 1176–1180.) The device described, which is designed for the lower a.f. range, converts a train of electrical pulses into a succession of hyperbolic waveforms of amplitude proportional to the interval between successive pulses. These waveforms are displayed on a c.r.o.; sudden changes in frequency are indicated immediately.

621.317.789.029.6 1829
**A Film Radiometer for Centimetre Wavelengths.**—J. A. Lane. (*Nature, Lond.*, 25th Feb. 1956, Vol. 177, No. 4504, p. 392.) Preliminary experiments are briefly described on the development of a device affording the possibility of accurate substitution of d.c. power for cm-λ power. A narrow strip of resistive film is arranged transversely in a standard 3-cm-band waveguide, between the centres of the broad faces. With a reflecting plunger fixed at a distance $\lambda_g/4$ behind the strip, a voltage s.w.r. of 0·9 or better can be achieved over a 10% bandwidth. The power can be determined by observing either the change of resistance or the rise in temperature.

621.318.4(083.74) 1830
**A Standard of Mutual Inductance.**—J. T. Henderson & M. Romanowski. (*Canad. J. Phys.*, Dec. 1955, Vol. 33, No. 12, pp. 856–870.) The construction and measurement of a Campbell-type standard mutual inductor for the National Research Council of Canada is described. Its calculated value is 0·010 007 $24_8$ H, with and error ≯ 13 parts per million.

621.318.4(083.74) 1831
**Considerations on the Primary Winding of the Campbell Standard Inductor.**—M. Romanowski & P. A. Fraser. (*Canad. J. Phys.*, Dec. 1955, Vol. 33, No. 12, pp. 871–885.) Estimates are made of the effect of the presence of the quartz cylinder and of the finite cross-section of the primary wire on the value of the standard inductor described by Henderson & Romanowski (1830 above).

## OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534-8 1832
**Industrial Applications of Ultrasonics.**—E. G. Richardson. (*Brit. J. appl. Phys.*, Dec. 1955, Vol. 6, No. 12, pp. 413–415.) Modern techniques are described with particular reference to echo detecting, high-frequency agitation and metallurgical applications. The possibilities and limitations of ultrasonics for these purposes are discussed.

538.566.029.6:541.126 1833
**Microwave Observation of Detonation.**—J. L. Farrands & G. F. Cawsey. (*Nature, Lond.*, 7th Jan. 1956, Vol. 177, No. 4497, pp. 34–35.) A method of measuring the velocity of detonation of high explosives under contained conditions is described, based on principles of microwave interferometry.

621-52:681.142 1834
**Digital Methods in Control Systems.**—D. F. Nettell. (*Electronic Engng*, March 1956, Vol. 28, No. 337, pp. 108–114.) The application of digital computer techniques to factory automation is discussed, with special reference to the use of digital methods with existing analogue installations.

621.317.39:531.71 1835
**Noncontacting Gages for Nonferrous Metals.**—R. B. Colten. (*Electronics*, March 1956, Vol. 29, No. 3, pp. 171–173.) Two gauges for Cu and Al from 0·003 to 0·5 in. thick are based on measurement of skin effect. Cu strip passing the pickup head is gauged and recorded at a rate of 300 ft/min.

621.317.39:621.383.27 1836
**Aerosoloscope counts Particles in Gas.**—E. S. Gordon, D. C. Maxwell, Jr, & N. E. Alexander. (*Electronics*, March 1956, Vol. 29, No. 3, pp. 188–192.) Light scattered by an aerosol beam is received by a photomultiplier and the resulting random voltage pulses are analysed in a pulse-height discriminator and counted in twelve groups, thus giving the number and size distribution of the particles. The instrument is accurate for particles of diameter 1–64 μ, and concentrations up to 10 000 particles/cm³ can be dealt with, at a maximum counting rate of 100/sec.



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621.326.73 **1837**

**A Uniform Blackbody Light Source excited by Radio Frequency.**—S. C. Peek. (*J. Soc. Mot. Pict. Telev. Engrs*, Dec. 1955, Vol. 64, No. 12, pp. 671–673. Discussion, p. 673.) The lamp comprises a $\frac{1}{16}$-in. tantalum carbide disk supported by a zirconium oxide rod and heated by r.f. induction. The lamp can be operated at a brightness of up to 50 000 candles/in².

621.384.6: 621.319.3 **1838**

**An Electrostatic Particle Accelerator.**—D. R. Chick & D. P. R. Petrie. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 132–145. Discussion, pp. 152–154.) Equipment combining a pressurized charged-belt e.s. generator and a multi-section ion-accelerator tube is described. Proton beams have been obtained with energy up to 3·25 MeV and an energy resolution of 1 in 1 200.

621.384.612 **1839**

**Synchrotron Oscillations in Strong-Focusing Accelerators.**—L. L. Goldin & D. G. Koškarev. (*Nuovo Cim.*, 1st Dec. 1955, Vol. 2, No. 6, pp. 1251–1268. In English.) Linear theory is presented.

621.384.612 **1840**

**Gas Scattering in a Strong-Focusing Electron Synchrotron.**—M. J. Moravcsik & J. M. Sellen, Jr. (*Rev. sci. Instrum.*, Dec. 1955, Vol. 26, No. 12, pp. 1158–1164.)

621.385.833 **1841**

**The EM 75 kV, an Electron Microscope of Simplified Construction.**—A. C. van Dorsten & J. B. Le Poole. (*Philips tech. Rev.*, Aug. 1955, Vol. 17, No. 2, pp. 47–59.) An instrument giving a resolving power of at least 100 Å has magnetic condenser, objective and projector lenses.

621.385.833 **1842**

**The Testing of some Adjustable Permanent-Magnet Electron Lenses.**—G. Langner. (*Optik, Stuttgart*, 1955, Vol. 12, No. 12, pp. 554–562.)

621.385.833: 538.221 **1843**

**Magnetic Contrast in Electronic Mirrors and Observation of Domains in a Ferromagnetic Material.**—Spivak, Prilezhaeva & Azovtsev. (See 1794.)

621.386: 778.33: 621.383.8: 621.385.832 **1844**

**X-Ray Images made Visible by means of a Television Pickup Tube responding to X Rays.**—Keller & Ploke. (See 1901.)

621.387.422 **1845**

**The Discharge Mechanism in an Argon-Filled Proportional Counter.**—K. Schütt. (*Z. Phys.*, 22nd Dec. 1955, Vol. 143, No. 4, pp. 489–512.)

621.389 **1846**

**Applications of the Optics of Electric Charges to Mass Spectrometry.**—R. Vauthier. (*Ann. Phys., Paris*, Nov./Dec. 1955, Vol. 10, pp. 968–1025.)

621.9: 537.523.4 **1847**

**High-Frequency Electro-spark Machining of Hard Metals.**—(*Microtecnic*, 1955, Vol. 9, No. 5, pp. 267–271.) The technique discussed involves production of a nonoscillating spark discharge lasting a few microseconds, with current density of the order of $10^5$ A/mm². Some details are given of a machine with a spark frequency variable from 2 500/sec to tens of thousands per sec.

## PROPAGATION OF WAVES

621.396.11 **1848**

**Propagation of Electromagnetic Waves over a Flat Earth across Two Boundaries separating Three Different Media.**—K. Furutsu. (*J. Radio Res. Labs, Japan*, July 1955, Vol. 2, No. 9, pp. 239–279.) A theoretical paper. Formulae involving integrals are derived for field strength; calculated values are compared with observed values for several examples of propagation across a land/water boundary.

621.396.11: 551.510.535 **1849**

**Divergence Factor of the Wave Reflected from the Surface of the Ionosphere.**—H. Uyeda, T. Kitsunezaki & Y. Arima. (*J. Radio Res. Labs, Japan*, July 1955, Vol. 2, No. 9, pp. 311–327.) The effect of curvature of the surface of the ionosphere on the field strength of the reflected wave is discussed. A 'divergence factor' expressing the energy loss on reflection from an infinitesimally small area is defined and a formula for it is deduced. The results for ellipsoidal and sinusoidal ionosphere surfaces are examined in detail.

621.396.11: 551.510.535 **1850**

**Radio Observations of the Ionosphere at Oblique Incidence.**—J. H. Chapman, K. Davies & C. A. Littlewood. (*Canad. J. Phys.*, Dec. 1955, Vol. 33, No. 12, pp. 713–722.) Automatic vertical-incidence sounding equipment has been adapted for use in oblique-incidence measurements over the 2 355-km path between Ottawa and Saskatoon. Typical records are shown and discussed. Accepted theory relating vertical-incidence and oblique-incidence propagation is verified by comparison with vertical-incidence soundings taken at a station 200 km from the mid-point of the path. See also 1138 of 1955 (Cox & Davies).

621.396.11: 621.396.674 **1851**

**Propagation of Transient Fields from Dipoles near the Ground.**—H. Poritsky. (*Brit. J. appl. Phys.*, Dec. 1955, Vol. 6, No. 12, pp. 421–426.) The analysis presented is based on the resolution of a spherical wave into proper plane waves. A double-integral representation is obtained for the Hertz potential of the field. For a vertical dipole on the ground one of the integrations is carried out for the region above the ground and for a conical region underground, while the second integration is carried out for special directions and locations.

621.396.11.029.55 **1852**

**Analysis of Sky-Wave Field Intensity.**—S. N. Mitra & R. B. L. Srivastava. (*Indian J. Phys.*, April & May 1955, Vol. 29, Nos. 4 & 5, pp. 167–178 & 227–242.) Measurements of the field strength of s.w. transmissions from Bombay, Calcutta and Madras made at Delhi over the period 1942–1952 are analysed. The yearly, seasonal and monthly variations and their correlation with sunspot numbers are shown graphically. An unexplained feature of the observations is the correlation of night-time field strength with solar activity. The observations are compared with values calculated by the C.R.P.L. and S.P.I.M. methods; neither of these is strictly applicable to propagation conditions in India or in the tropics generally.

621.396.11.029.55 **1853**

**Ionospheric Propagation of Decametre Waves and Form of Second-Marking Pulses in Standard Amplitude-Modulated Transmissions.**—J. Bouchard & A. Helaine. (*C. R. Acad. Sci., Paris*, 23rd Jan. 1956, Vol. 242, No. 4, pp. 480–482.) Continuation of the investigation reported previously by Bouchard (1783 of 1953). Oscillograms of the



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time-signal pulses from WWV and WWVH have been recorded and examined in relation to propagation conditions at the relevant time. Various forms of distortion are observed.

621.396.11.029.55: 551.510.535 **1854**

**A Study of Ionospheric Propagation by means of Ground Back-Scatter.**—E. D. R. Shearman. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 203–209. Discussion, pp. 232–235.) "The results of a year's observations in southern England of long-range back-scatter are analysed. A pulse transmitter coupled to alternative directional aerials was used, and transmissions were made at noon each day on a number of frequencies between 10 and 27 Mc/s. The echo patterns observed in winter were simple and were formed by echoes from the ground just beyond the skip distances for one- and two-hop $F_2$-layer propagation. In summer, however, ground echoes returning by way of the $E_s$, E and $F_1$ layers arrived nearly simultaneously and were difficult to distinguish. The marked increase in $E_s$ ionization in summer could be seen clearly from the echo patterns. Examples of fixed frequency range-time recordings ($p't$) of back-scatter are given. On one record echoes can be seen at ranges corresponding to each of the ground reflection points for four-hop $F_2$ propagation between England and Malaya. The application of the $pti$ technique to the direct measurement of maximum usable frequencies is described. To assess the accuracy of the back-scatter technique of skip-distance measurement, comparisons were made between measured scatter ranges calculated from vertical-incidence ionosphere measurements. The measured ranges were consistently shorter than those calculated. It is uncertain whether this discrepancy arises from approximations in the theory used for the calculations from vertical-incidence data or from inadequate directivity in the aerials used in the scatter measurements. Comparisons of scatter ranges with direct measurements of m.u.f. over the same path are considered desirable to resolve this uncertainty."

621.396.11.029.55: 551.510.535 **1855**

**The Technique of Ionospheric Investigation using Ground Back-Scatter.**—E. D. R. Shearman. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 210–223. Discussion, pp. 232–235.) "The skip distance in short-wave propagation is measured by observing the time delay of echoes scattered from the earth's surface beyond the skip distance. A theoretical study shows that the method should give good accuracy in determining skip distance, but cannot yield unique values of the height and critical frequency of an ionospheric layer at a distant point. The radar equation is used to find the intensity of back-scatter from the ground, and an approximate calculation indicates that the irregularities present on land and sea should be sufficient to explain the observed echo strength. The effect of ray focusing by the ionosphere is considered. Experimental results confirm the conclusions of other workers that the predominant sources of echoes are on the ground and not in the E region. An empirical correction for the effect of the earth's magnetic field shows that no error in the location of the sources is introduced by using no-field theory in the analysis of results."

621.396.11.029.55: 551.510.535 **1856**

**An Experiment to test the Reciprocal Radio Transmission Conditions over an Ionospheric Path of 740 km.**.—R. W. Meadows. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 224–226. Discussion, pp. 232–235.) "Two-way pulse transmissions made simultaneously on the same frequency (5·1 Mc/s approximately) between Slough and Inverness (740 km) are described. An aerial common to transmitter and receiver was used at each terminal, and the fading patterns displayed at each end were compared visually: the Inverness display was relayed to Slough over a Post Office trunk line for this purpose. The fading of corresponding echoes was found to be non-reciprocal for about 1% of the time during a total period of observation of about 15 daylight hours spread over 13 days in May, 1954. The precautions taken to ensure that the effects were ionospheric and not instrumental are outlined."

621.396.11.029.55: 551.510.535 **1857**

**An Experimental Test of Reciprocal Transmission over Two Long-Distance High-Frequency Radio Circuits.**—F. J. M. Laver & H. Stanesby. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 227–232. Discussion, pp. 232–235.) "The results obtained both across the North Atlantic and between Australia and the United Kingdom show that at times the loss in both directions is substantially the same, and that at other times the loss difference can rise to values of the order of 5 or 10 dB. Usually the loss differences were such that signals outwards from the United Kingdom suffered the greater attenuation, but without further evidence it would be unwise to assume that this tendency is permanent."

621.396.11.029.6: 551.510.52 **1858**

**On the Propagation of Ultra-short Waves beyond the Horizon.**—K. Tao. (*Japanese J. Geophys.*, May 1954, Vol. 1, No. 1, pp. 27–79.) General analysis is presented for propagation in the diffraction region. The propagation modes are considered for a three-layer troposphere with the refractive index varying linearly with height in each layer. Refractive-index gradients are calculated from aerological data and standard propagation is studied by comparing calculated and observed values of field strength.

621.396.11.029.62 **1859**

**Uses of Diffraction Effect of Mountains for V.H.F. Radiocommunication.**—T. Kono, M. Hirai & Y. Uesugi. (*J. Radio Res. Labs, Japan*, July 1955, Vol. 2, No. 9, pp. 293–309.) Results with a receiver placed in the diffraction field at a point where the received field strength is high and not critically dependent on location show that the field strength varies very little with time; reliable communication can be established over a distance of 300–400 km. See also 2093 of 1955 (Kono et al.).

621.396.11.029.62 **1860**

**V.H.F. Propagation by Ionospheric Scattering and its Application to Long-Distance Communication.**—W. J. Bray, J. A. Saxton, R. W. White & G. W. Luscombe. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 236–257. Discussion, pp. 257–260.) "The paper describes an investigation of the propagation of v.h.f. radio waves by scattering from the E-region of the ionosphere. The dependence of the characteristics of the received signal on frequency, distance and aerial directivity is examined, and observations are made on the diurnal and seasonal variations of the received signal strength; the results are discussed in relation to existing theories. Investigations are also described on the suitability of this form of propagation for the transmission of frequency-shift telegraphy signals, and for telephony signals transmitted by single-sideband amplitude modulation, and by phase modulation, of a carrier. A form of wave-angle diversity reception which yields a substantial improvement in the performance of a telegraphy system is described. The possible applications of v.h.f. scatter propagation to commercial services are discussed."



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## RECEPTION

621.376.332: 621.374.32 **1861**

**Low-Distortion F.M. Discriminator.**—M. G. Scroggie. (*Wireless World*, April 1956, Vol. 62, No. 4, pp. 158–162.) The operation of a resistance-coupled pulse-counting discriminator circuit is described. A circuit diagram of the limiter and discriminator and the characteristic curves are given.

621.396.812.3 **1862**

**Diversity Reception with Correlated Signals.**—H. Staras. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 93–94.) The variation of diversity advantage with degree of correlation of the signals at two spaced receivers is examined.

621.396.82 **1863**

**Required Interference Protection Ratios for the Field Strengths of Two Medium-Wave Transmitters as a Function of their Frequency Separation.**—E. Belger & F. von Rautenfeld. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, 1955, Vol. 7, Nos. 11/12, pp. 235–237.) A preliminary report is presented of listener tests made on two simultaneous transmissions at frequencies in the region of 1 Mc/s, using two commercially available broadcast receivers, one wide-band and the other narrow-band. The required interference protection ratios and the relative strengths of carrier and modulation interference effects are plotted as functions of frequency separation.

621.396.822: 621.376.232.2 **1864**

**On the Time Constants of Linear Detectors used in Radio Noise Measurements.**—K. Kawakami & H. Akima. (*J. Radio Res. Labs, Japan*, July 1955, Vol. 2, No. 9, pp. 221–234.) The relations between output voltage and detector time constant are investigated for various types of radio noise and a method of waveform determination is deduced. Noise is classified according to the output characteristic obtained when the detector circuit constants are varied; a 'sharpness factor' and a 'fineness factor' are defined.

## STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 **1865**

**A Class of Binary Signaling Alphabets.**—D. Slepian. (*Bell Syst. tech. J.*, Jan. 1956, Vol. 35, No. 1, pp. 203–234.)

621.396.11.029.62 **1866**

**V.H.F. Propagation by Ionospheric Scattering and its Application to Long-Distance Communication.**—Bray, Saxton, White & Luscombe. (See 1860.)

621.396.41 + 621.395.43]: 621.376.3 **1867**

**An Extended Analysis of Echo Distortion in the F.M. Transmission of Frequency-Division Multiplex.**—R. G. Medhurst & G. F. Small. (*Proc. Instn elect. Engrs*, Part B, March 1956, Vol. 103, No. 8, pp. 190–198.) By a combination of analytical and semi-empirical methods, Albersheim & Schafer's results (2022 of 1952) are extended to cover a wider range of cases. See also 247 of 1954 (Medhurst).

621.396.93 + 621.396.96 **1868**

**Symposium on Marine Communications and Navigation.**—(See 1726.)

621.396.97: 621.396.82 **1869**

**Improvement of Reception in Shared-Channel Operation by means of Frequency Offset.**—E. Belger & F. von Rautenfeld. (*Tech. Hausmitt. Nordw-Dtsch. Rdfunks*, 1955, Vol. 7, Nos. 11/12, pp. 232–234.) Listener tests indicate that the interference protection ratio required in a shared channel is increased if the carriers are separated by about 2 c/s but is slightly reduced if the separation is about 15 c/s. When the channel is shared by a number of transmitters two or three different frequencies may be used depending on the frequency constancy of the transmitters.

## SUBSIDIARY APPARATUS

621.316.722.1 **1870**

**Mains-Voltage Stabilizers.**—R. B. Stephens. (*Philips tech. Rev.*, July 1955, Vol. 17, No. 1, pp. 1–9.) A fast-acting stabilizer is described combining features of the magnetic and feedback types. The voltage-sensitive element is a bridge containing an indirectly heated thermistor. A stability to within $\pm$ 0·5% over the temperature range 10–50°C can be achieved for mains voltage fluctuations between 180 and 250 V, mains frequency variations between 47 and 51·5 c/s, and load variations from no load to full load. Recovery time is 1–2 cycles.

621.35: 539.169 **1871**

**Nuclear Batteries: Types and Possible Uses.**—A. Thomas. (*Nucleonics*, Nov. 1955, Vol. 13, No. 11, pp. 129–133.)

621.352.32 **1872**

**Depolarization of Electrochemical Cells containing Manganese Dioxide.**—J. Brenet, P. Malessan & A. Grund. (*C. R. Acad. Sci., Paris*, 4th Jan. 1956, Vol. 242, No. 1, pp. 111–112.)

621.355 **1873**

**Recent Patents on Electrical Accumulators.**—L. Jumau. (*Rev. gén. Élect.*, Nov. & Dec. 1955, Vol. 64, Nos. 11 & 12, pp. 537–554 & 602–616.) For previous review, see 2230 of 1954.

## TELEVISION AND PHOTOTELEGRAPHY

621.397.24 **1874**

**Developments in Closed-Circuit Television.**—M. H. Kraus. (*Elect. Engng, N.Y.*, Nov. 1955, Vol. 74, No. 11, pp. 974–979.) Multichannel distribution systems are discussed with particular reference to systems installed at Fort Monmouth and at the Case Institute of Technology. To be published in *Trans. Amer. Inst. elect. Engrs*, Part I, *Communication and Electronics*, 1955, Vol. 74.

621.397.5: 535.623 **1875**

**American Colour Television: the Present State.**—D. C. Birkinshaw. (*J. Telev. Soc.*, Oct.–Dec. 1955, Vol. 7, No. 12, pp. 509–515.) Report based on a survey made in April 1955. It is concluded that premature launching of colour television in Great Britain should be guarded against, that the picture tube is of paramount importance, and that a more sensitive camera is needed to make outside broadcasts satisfactory.

621.397.5: 535.623 **1876**

**Recent Developments in Colour Television.**—L. C. Jesty. (*J. Telev. Soc.*, Oct.–Dec. 1955, Vol. 7,



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No. 12, pp. 488–508.) Text of a paper read to the Society in April 1955. Various recent experiments in the U.S.A. and Great Britain are referred to. The importance of the picture tube is emphasized and possible alternatives to the tricolor-phosphor-dot shadow-mask type are mentioned, including flat constructions. Fundamental changes in television transmission systems by 1970 or 1980 are considered likely; for instance, a system in which each picture point is permanently associated with an individual channel would not be impossible.

621.397.6: 535.623 **1877**

**Fixing the Value of the Colour Carrier in a European Colour-Television System based on the N.T.S.C. System.**—F. Jaeschke. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, 1955, Vol. 7, Nos. 11/12, pp. 224–228.) Investigations of the best method of adapting the N.T.S.C. system to the 625-line standards lead to the recommendation of a colour-subcarrier frequency of 4·210 937 5 Mc/s; a fixed phase relation between sound and colour carriers is then possible. Combinations of frequency dividers, modulators and filters for effecting the necessary frequency conversions are described. See also 1878 below.

621.397.6: 535.623 **1878**

**The Position of the Colour Subcarrier in a Possible Adaptation of the N.T.S.C. System to the 625-Line C.C.I.R. Standard.**—F. Below & E. Schwartz. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, 1955, Vol. 7, Nos. 11/12, pp. 229–232.) The frequency corresponding on the C.C.I.R. standard to the N.T.S.C. colour-subcarrier frequency is about 4·26 Mc/s. Reasons are given for choosing a lower frequency, particularly 4·101 562 5 Mc/s; this is easier to divide than that recommended by Jaeschke (1877 above). A simple frequency-conversion arrangement is described. The final choice will be influenced by results of experiments in progress.

621.397.6: 621.317.3 **1879**

**State of Standardization of Test and Measurement Methods for Television Transmission Technique.**—J. Müller. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, 1955, Vol. 7, Nos. 11/12, pp. 209–216.) Test methods recommended by the German authorities are discussed and compared with those used in other countries. See also 1489 of May (Macek).

621.397.61 **1880**

**Black-Level Control in Television Pickup Apparatus.**—W. Dillenburger. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, 1955, Vol. 7, Nos. 11/12, pp. 217–223.) An examination is made of the extent to which the fly-back potential of different types of pickup apparatus bears a constant relation to picture black level. Clamp circuits are discussed; operation is facilitated by black-level control at the lowest brightness level. The control process is imperceptible with circuit time constants of 0·5–1 sec. An improved automatic black-level control circuit is described.

621.397.62: 535.623 **1881**

**Color Television Receiver Design—a Review of Current Practice** [in the U.S.A.].—R. G. Clapp, E. G. Clark, G. Howitt, H. E. Beste, E. E. Sanford, M. O. Pyle & R. J. Farber. (*Proc. Inst. Radio Engrs*, March 1956, Vol. 44, No. 3, pp. 297–321.) The review deals with the design of commercial receivers using shadow-mask picture tubes.

621.397.62: 535.623 **1882**

**Experimental Colour Receiver.**—H. A. Fairhurst. (*Wireless World*, March & April 1956, Vol. 62, Nos. 3 & 4, pp. 112–118 & 183–187.) The design of a receiver for the British N.T.S.C. system (3095 of 1955) is described. A 21-in. R.C.A. shadow-mask c.r. tube is used.

621.397.62 + 621.317.326]: 621.385.2 **1883**

**The Response of Diode Circuits to Periodic Pulses.**—R. Suhrmann. (*Nachrichtentech. Z.*, Dec. 1955, Vol. 8, No. 12, pp. 659–665.) Analysis is presented relevant to the operation of diodes for restoring the d.c. component in television receivers and for peak-voltage measurements. Calculations are based on the initial exponential region of the diode characteristic. For practical purposes the resistance of the diode during the charging of the associated capacitor can be assumed constant; its value may be anything from 1 to 100 kΩ.

621.397.7 **1884**

**The Marconi Television Centre.**—T. W. Pace. (*J. Telev. Soc.*, Oct.–Dec. 1955, Vol. 7, No. 12, pp. 520–522.) Description of a studio in London, specially equipped for equipment testing and demonstrating and for personnel training.

621.397.813: 621.397.611 **1885**

**Television Vertical Aperture Compensation.**—A. C. Schroeder & W. G. Gibson. (*J. Soc. Mot. Pict. Telev. Engrs*, Dec. 1955, Vol. 64, No. 12, pp. 660–670.) A method is described involving defocusing and refocusing at a rapid rate, thus yielding high- and low-resolution signals whose difference gives the aperture-compensated signal. A similar method using vertical-deflection wobble rather than focus wobble results in vertical aperture compensation only.

## TRANSMISSION

621.396.61: 621.317.32 **1886**

**A Method for the Direct Measurement of Spurious Emissions.**—Kurokawa, Takahashi & Arai. (See 1811.)

## VALVES AND THERMIONICS

537.58: 537.311.33 **1887**

**Thermionic Constants of Semiconductors.**—K. S. Krishnan & S. C. Jain. (*Nature, Lond.*, 11th Feb. 1956, Vol. 177, No. 4502, p. 285.) The method of determining the constants described previously [3467 of 1952 (Jain & Krishnan)] is used to investigate Ni ribbons coated with triple carbonates of Ba, Sr and Ca. The currents corresponding to zero field fitted Richardson's equation well, with $\phi$ = 1·55 eV and $A$ = 48 A. cm$^{-2}$ deg$^{-2}$.

621.314.63 **1888**

**Note on a Particular** [semiconductor] **Structure permitting Production of High-Frequency Oscillations.**—A. Leblond & R. Gentner. (*C. R. Acad. Sci., Paris*, 30th Jan. 1956, Vol. 242, No. 5, pp. 621–623.) Experiments have been made with a *p-i* diode having metal electrodes making linear-resistance contacts. For thicknesses of the *i* region not greater than about a dozen microns, the low-temperature characteristic exhibits a negative-resistance region; stable relaxation oscillations at 35 Mc/s have been observed.



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621.314.632: 537.311.33 **1889**

**The Influence of Frequency on the Rectifying Properties of Semiconducting Diodes at Low Alternating Voltages.**—S. G. Kalashnikov & N. A. Penin. (*Zh. tekh. Fiz.*, June 1955, Vol. 25, No. 6, pp. 1111–1123.) The frequency dependence of the rectified current is explained in terms of the capacitance of the *p-n* junction. This capacitance is due to the injection of carriers into the junction, and also to the displacement current. Simple expressions are derived for the limiting frequency and the frequency dependence of the rectified current under various operating conditions. The effects of the semiconductor properties on the frequency characteristics are also discussed.

621.314.7 **1890**

**Diffused Emitter and Base Silicon Transistors.**—M. Tanenbaum & D. E. Thomas. (*Bell Syst. tech. J.*, Jan. 1956, Vol. 35, No. 1, pp. 1–22.) Techniques are described for making Si *n-p-n* transistors by diffusing impurities from the vapour phase. Base layers $3 \cdot 8 \times 10^{-4}$ cm thick have been produced. Characteristics are presented of a transistor for which $\alpha_0 = 0 \cdot 97$ and cut-off frequency is 120 Mc/s. The structure and design of these transistors are discussed. For a brief version, see *Electronics*, Feb. 1956, Vol. 29, No. 2, pp. 137–139 (Carroll).

621.314.7 **1891**

**A High-Frequency Diffused-Base Germanium Transistor.**—C. A. Lee. (*Bell Syst. tech. J.*, Jan. 1956, Vol. 35, No. 1, pp. 23–34.) Techniques of impurity diffusion and alloying in Ge are discussed. Examples are given of Ge *p-n-p* junction transistors in which $\alpha_0 = 0 \cdot 98$ and cut-off frequency is 500 Mc/s. For a brief version, see *Electronics*, Feb. 1956, Vol. 29, No. 2, pp. 137–139 (Carroll).

621.314.7: 621.3.015.3 **1892**

**Transfer Characteristic of Semiconductor Triodes.**—E. I. Adirovich & V. G. Kolotilova. (*C. R. Acad. Sci. U.R.S.S.*, 1st Dec. 1955, Vol. 105, No. 4, pp. 709–712. In Russian.) An approximate expression is given for a function $g(t)$ in terms of parameters of the region between the emitter and collector, and the expression is used in deducing the effect of (*a*) a step and (*b*) a rectangular emitter current pulse.

621.314.7: 621.373.431.2 **1893**

**Junction Transistors with Alpha Greater than Unity.**—H. Schenkel & H. Statz. (*Proc. Inst. Radio Engrs*, March 1956, Vol. 44, No. 3, pp. 360–371.) When the collector voltage of a junction transistor is raised to a level just below breakdown voltage, multiplication of charge carriers occurs and the alpha value rises above unity. The transistor characteristic corresponding to this condition of operation is investigated; the characteristic may be negative over a limited region. A free-running blocking oscillator using one transistor operated in this condition, and no transformer, is described.

621.314.7: 621.396.822 **1894**

**Measurements of Spontaneous Fluctuations in Currents with Different Carriers in Semiconductor Barrier Layers.**—W. Guggenbühl & M. J. O. Strutt. (*Helv. phys. Acta*, 15th Dec. 1955, Vol. 28, No. 7, pp. 694–704. In German.) Measurements under 'white-noise' conditions indicate that when current in *p-n* junctions is produced either by applied voltage or by spontaneous creation of carriers, the fluctuations are consistent with Schottky's equations. In some recently developed alloyed-junction transistors the junction superimposes no additional fluctuations on the injected current, so that noise factors as good as those of high-vacuum valves can be obtained. See also 2778 and 3781 of 1955.

621.383.2: 621.317 **1895**

**The Photodianode: Modulation of the Differential Current by an Alternating Magnetic Field.**—L. Deloffre, É. Pierre & J. Roig. (*C. R. Acad. Sci., Paris*, 4th Jan. 1956, Vol. 242, No. 1, pp. 98–100.) The device described previously (1737 of 1955 and back references) can conveniently be operated with a magnetic field of the order of 30 oersted applied parallel to the anodes. Frequencies up to 75 kc/s have been used.

621.383.27 **1896**

**High-Speed Electron Multiplication by Transmission Secondary Electron Emission.**—E. J. Sternglass. (*Rev. sci. Instrum.*, Dec. 1955, Vol. 26, No. 12, p. 1202.) Electron multipliers based on secondary emission from the rear sides of a series of plane-parallel insulating films is suggested. Tests on an experimental seven-stage device gave a delay in the response of $(3 \pm 1) \times 10^{-8}$ sec, with a pulse rise time of $10^{-9}$ sec. The results are discussed in relation to the use of such devices for resolving short time intervals.

621.383.4: 535.371.07 **1897**

**Solid-State Image Intensifiers.**—G. Diemer, H. A. Klasens & J. G. van Santen. (*Philips Res. Rep.*, Dec. 1955, Vol. 10, No. 6, pp. 401–424.) "A theory is given of the characteristics of solid-state image intensifying screens consisting of a photoconducting and an electroluminescent layer, including the influence of positive internal feedback and negative electrical feedback. The possibilities of brightness as well as contrast amplification are discussed. With intermittent irradiation it is possible to increase the amplification factor by storage, due to the decay, or by triggering of a feedback amplifying-screen. In the latter case the gradation need not be lost. The dimensioning of the parameters with regard to specific applications (e.g. radar, X-ray images, television) is discussed. Preliminary experimental results are in agreement with theory. With X-rays a brightness-amplification factor of 30 was obtained with respect to a normal fluorescent X-ray screen."

621.383.42 **1898**

**Modifications of the Spectral Sensitivity Curve of Selenium Photocells under the Influence of Temperature Variations.**—G. Blet. (*C. R. Acad. Sci., Paris*, 4th Jan. 1956, Vol. 242, No. 1, pp. 95–98.) Measurements were made on cells of various types, at temperatures down to that of liquid helium. Complex variations of a generally similar nature were observed in all cases. Some results are shown graphically.

621.383.5: 546.28: 621.396.822 **1899**

**Photovoltaic Noise in Silicon Broad Area *p-n* Junctions.**—U. F. Gianola. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 51–54.) Photovoltaic cells of the type described by Fuller & Ditzenberger (1068 of 1955) exhibit a $1/f$ noise power spectrum under constant illumination. With varying illumination intensity the noise voltage exhibits a pronounced maximum. It is suggested that fluctuations in the primary photocurrent are produced as a result of traversing the junction; experimental evidence is presented in support of this view.



World Radio History

621.383.5: 546.28: 621.396.822 **1900**

**Noise in Silicon *p-n* Junction Photocells.**—G. L. Pearson, H. C. Montgomery & W. L. Feldmann. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, pp. 91–92.) "A silicon *p-n* junction photocell prepared by the gaseous diffusion process and biased in reverse showed no noise in excess of shot noise down to a frequency of 80 c/s in a dry atmosphere. In a humid atmosphere the excess noise was a factor of $3 \times 10^5$ above shot noise at 100 c/s and showed the familiar $1/f$ spectrum."

621.383.8: 621.385.832: 621.386: 778.33 **1901**

**X-Ray Images made Visible by means of a Television Pickup Tube responding to X Rays.**—M. Keller & M. Ploke. (*Z. angew. Phys.*, Dec. 1955, Vol. 7, No. 12, pp. 562–571.) An iconoscope tube with an amorphous selenium photosensitive screen is described. The Se layer is 150 $\mu$ thick, possesses good storage properties and is not affected by the atmosphere. By using this tube in a closed-circuit television system, high luminosity and high-contrast X-ray images are obtainable.

621.385 **1902**

**Irrotational Electron Beams.**—J. Coste & J. L. Delcroix. (*C. R. Acad. Sci., Paris*, 9th Jan. 1956, Vol. 242, No. 2, pp. 236–238.) Theory presented by Gabor (362 of 1946) is extended to deal with relativistic beams. The general equation for monodromic irrotational beams is derived.

621.385.029.6 **1903**

**Plasma Oscillations and Resonance Frequencies in a Magnetron in the Brillouin State.**—J. Coste & J. L. Delcroix. (*C. R. Acad. Sci., Paris*, 4th Jan. 1956, Vol. 242, No. 1, pp. 87–90.) The system considered is a cylindrical whole-anode magnetron with the electrons describing circles round the axis. Analysis is based on a perturbation method. In general, the oscillations in the transverse plane comprise both radial and tangential components. Resonance frequencies are calculated by considering the anode/cathode system as a coaxial cavity.

621.385.029.6 **1904**

**The O-Type Carcinotron Tube.**—P. Palluel & A. K. Goldberger. (*Proc. Inst. Radio Engrs*, March 1956, Vol. 44, No. 3, pp. 333–345.) The O-type carcinotron is a backward-wave oscillator valve developed in France. Starting conditions deduced theoretically are compared with experimental results. The effects of reflections at the ends of the delay line are discussed and approximate expressions are derived for the efficiency and for frequency pushing. Design and performance data are given for a series of valves in production; each type covers about one octave, the whole series covering the frequency range 1–12 kMc/s. The maximum beam voltage is 1·5 kV and the r.f. outputs range from 100 mW to 1 W.

621.385.029.6 (083.7) **1905**

**I.R.E. Standards on Electron Devices: Definitions of Terms related to Microwave Tubes (Klystrons, Magnetrons, and Traveling Wave Tubes), 1956.**—(*Proc. Inst. Radio Engrs*, March 1956, Vol. 44, No. 3, pp. 346–350.) Standard 56 I.R.E. 7.S1.

621.385.029.6: 537.533 **1906**

**Growing Waves due to Transverse Velocities.**—J. R. Pierce & L. R. Waller. (*Bell Syst. tech. J.*, Jan. 1956, Vol. 35, No. 1, pp. 109–125.) Conditions are derived for the propagation of antisymmetrical and symmetrical growing waves in neutralized electron beams in which all electrons have the same velocity in the direction of propagation, but in which there are streams of two or more velocities normal to the direction of propagation.

621.385.029.6: 621.372.2 **1907**

**Definition, Measurement and Character of the Phase Velocities in Systems with Periodic Structure.**—B. Epsztein & G. Mourier. (*Ann. Radioélect.*, Jan. 1955, Vol. 10, No. 39, pp. 64–73.) Analysis is presented elucidating the operation of lines with periodic structure in travelling-wave valves.

621.385.029.6: 621.372.2 **1908**

**Investigation of an Interdigital Line operating in the Vicinity of the Π Mode.**—A. Leblond. (*Ann. Radioélect.*, Jan. 1955, Vol. 10, No. 39, pp. 83–91.) The effect of radiation from the line is examined; though not in general negligible, it is not great enough to invalidate determinations of Π-mode frequency and field distribution reported previously [1204 of 1955 (Leblond & Mourier)].

621.385.029.6: 621.373.423 **1909**

**Investigation of an Interdigital Line used as Anode Circuit for an U.H.F. Magnetron Oscillator. Distortions of the Electromagnetic Field.**—A. Leblond. (*Ann. Radioélect.*, Jan. 1955, Vol. 10, No. 39, pp. 20–41.) Continuation of earlier work (289 of 1954). Effects due to mismatch of the output circuit are studied; these include modifications of the field distribution as compared with the unloaded condition for the same mode, and frequency pulling. Analysis is based directly on Maxwell's equations, without any simplifying assumptions.

621.385.032.2 **1910**

**Determination of the Shapes of Electrodes for Pierce-Type Electron Guns.**—R. Hechtel. (*Telefunken Ztg*, Dec. 1955, Vol. 28, No. 110, pp. 222–226. English summary, pp. 264–265.) A mathematical method is developed for obtaining a converging beam; its application is illustrated by the design of an electron gun with a semi-aperture angle of 45°.

621.385.032.2: 537.533 **1911**

**New Points of View in the Design of Electron Guns for Cylindrical Beams of High Space Charge.**—M. Müller. (*J. Brit. Instn Radio Engrs*, Feb. 1956, Vol. 16, No. 2, pp. 83–94.) English translation of paper abstracted in 2478 of 1955.

621.385.032.21: 537.533 **1912**

**Electron Emission from a Lattice Step on Clean Tungsten.**—J. K. Trolan, J. P. Barbour, E. E. Martin & W. P. Dyke. (*Phys. Rev.*, 15th Dec. 1955, Vol. 100, No. 6, pp. 1646–1649.) Experiments using pulsed T-F (temperature and field) emission are described; they afford the basis of technique for studying the transport of cathode material.

621.385.032.21: 621.396.822 **1913**

**The Influence of Cathode Standing Waves on Valve Stability.**—W. W. H. Clarke. (*Brit. J. appl. Phys.*, Dec. 1955, Vol. 6, No. 12, pp. 433–441.) Experimental results indicate that the changes in the space-charge patterns of the virtual cathode of a valve are determined by the local variations of emission properties and by the boundary conditions of the cathode. Each pattern is associated with a particular current characteristic, so that a valve can have several preferred emission levels for constant applied potentials, intermediate



World Radio History

values of current being associated with patterns in a slightly unstable condition. The patterns change coherently and cause discrete current changes. The flicker effect may be related to these changes.

621.385.032.216 **1914**

**Diffusion of Impurity Atoms in an Oxide Cathode through the Interface Layer.**—N. D. Morgulis & Yu. G. Ptushinski. (*Zh. tekh. Fiz.*, June 1955, Vol. 25, No. 6, pp. 1157–1159.) The introduction of Si as an activator into the core of an oxide cathode results in the formation of $Ba_2SiO_4$ at the interface between the core and the oxide layer. This has a detrimental effect on the life of the cathode, possibly because with the growth of the $Ba_2SiO_4$ layer the diffusion of activating atoms from the core into the oxide layer becomes progressively more difficult. To verify this, an investigation was carried out using tracer atoms; the results are discussed.

621.385.032.216 **1915**

**D.C. and Pulsed Emission from L-Cathodes.**—I. Brodie. (*Proc. phys. Soc.*, 1st Dec. 1955, Vol. 68, No. 432B, pp. 1146–1148.) The difference between pulsed and d.c. emission from oxide cathodes [2091 and 3590 of 1949 (Wright)] is found also, to a lesser degree, in L-type cathodes and in these is considered to be due to partial removal of Ba from the cathode surface by positive-ion or gas bombardment.

621.385.032.216 **1916**

**A New Pressed Dispenser Cathode.**—P. P. Coppola & R. C. Hughes. (*Proc. Inst. Radio Engrs*, March 1956, Vol. 44, No. 3, pp. 351–359.) Description of the development of a moulded cathode consisting of CaBa aluminate dispersed in a porous matrix of W-Mo alloy. This type of cathode is suitable for operation in the temperature range 1 000–1 200°C, and has an emission density of 10 A/cm² and a lifetime > 5 000 h at an operating temperature of 1 130°C.

621.385.2.032.216 **1917**

**Effect of the Cathode Work Function on the Space-Charge-Limited Characteristics of Plane Diodes.**—C. R. Crowell. (*J. appl. Phys.*, Jan. 1956, Vol. 27, No. 1, p. 93.) An extension of Ferris's work (2099 of 1949). The diode characteristic is shown to be independent of the cathode work function until the current drawn is an appreciable fraction of the saturation current.

621.385.832: 621.397.6 **1918**

**Resolving Power of the Image Converter with Uniform Electrostatic and Magnetic Fields.**—G. Wendt. (*Ann. Radioélect.*, Jan. 1955, Vol. 10, No. 39, pp. 74–82.) A calculation is made of the electron density distribution in the image point, taking the initial Maxwellian velocity distribution into account. The results are extended to the image of a line and a pattern of lines, and are compared with observations. Using a television test pattern, a definition of 100 lines/mm has been obtained on a screen of diameter 50 mm with an anode voltage of only 5 kV.

621.385.832.001.4: 621.317.3 **1919**

**Testing Cathode-Ray Tubes.**—R. D. Nixon. (*Elect. J.*, 16th Dec. 1955, Vol. 155, No. 4044, pp. 2011–2012.) Brief details are given of life tests carried out by a manufacturer.

621.387 **1920**

**Impedance-Frequency Characteristics of some Glow-Discharge Tubes.**—F. A. Benson & G. Mayo. (*Electronic Engng*, March 1956, Vol. 28, No. 337, pp. 124–126.) Measurements in the frequency range 20 c/s–50 kc/s show that in every case the impedance of the tube increases considerably with frequency. The importance of ion inertia effects is emphasized.

621.387 **1921**

**Ignition Sensitivity and Ignition Delay Time of Gas-Filled Triodes and Tetrodes.**—E. Knoop. (*Z. angew. Phys.*, Dec. 1955, Vol. 7, No. 12, pp. 575–582.) Results of a theoretical and experimental investigation indicate that for good sensitivity the valve should be designed for a high geometrical penetration coefficient and the gas chosen should have a large ionization cross-section at not too low a pressure and at high ion velocity. The parameters and processes determining the delay time are discussed; the occurrence of maximum values of delay time is explained in relation to the adequacy of the supply of ions in the grid-anode space.

621.387: 537.56 **1922**

**The Gas-Multiplier: a New Type of Electron Multiplier.**—C. H. Vincent. (*Nature, Lond.*, 25th Feb. 1956, Vol. 177, No. 4504, pp. 391–392.) A multi-stage device based on use of the Townsend electron avalanche process is described; multiplication by the $\alpha$ process is permitted, while the accompanying processes which cause positive feedback by releasing further electrons in the input region are restricted. The electrodes dividing the chamber into stages are plane, parallel and equally spaced, and have small holes in a central area. Conditions for operational stability are discussed.

## MISCELLANEOUS

621.3: 061.3 **1923**

**1956 I.R.E. National Convention Program.**—(*Proc. Inst. Radio Engrs*, March 1956, Vol. 44, No. 3, pp. 382–417.) Includes abstracts of the papers presented.

621.3.002.2 **1924**

**Making Photo-etched Circuits in Your Workshop.**—R. H. Dorf. (*Radio-Electronics*, Dec. 1955, Vol. 26, No. 12, pp. 56–58 & Jan. 1956, Vol. 27, No. 1, pp. 139 . . 148.) Simple instructions are given for preparing the circuit drawing, making the negative, sensitizing the laminated panel, exposing the panel, developing the image, and etching.

621.37 + 621.396]: 519.2 **1925**

**Some Problems of Fluctuation in Radio.**—J. C. Simon. (*Ann. Radioélect.*, Jan. 1955, Vol. 10, No. 39, pp. 3–19.) Statistical methods for summing vectors with random phase angles are discussed and the concept of correlation function is introduced. The theory is applied to an examination of various problems including multiple reflections on a transmission line, radiation from a large number of sources, fluctuations of a radar echo, influence of phase errors on aerial characteristics.

621.37/.39].004.6 **1926**

**Prediction of Electronic Equipment Reliability.**—V. Harris & M. M. Tall. (*Elect. Engng, N.Y.*, Nov. 1955, Vol. 74, No. 11, pp. 994–997.) A method is described based on failure data collected by the U.S. Navy.

621.385.832.002.2: 621.397.621.2 **1927**

**The Television Cathode-Ray-Tube Factory at Ulm** [W. Germany].—C. F. Hühn. (*Telefunken Ztg*, Dec. 1955, Vol. 28, No. 110, pp. 215–222. English summary, p. 264.) A plant completed in 1955 with a planned output of 50 000 picture tubes per month is described. Photographs and a flow chart are presented.



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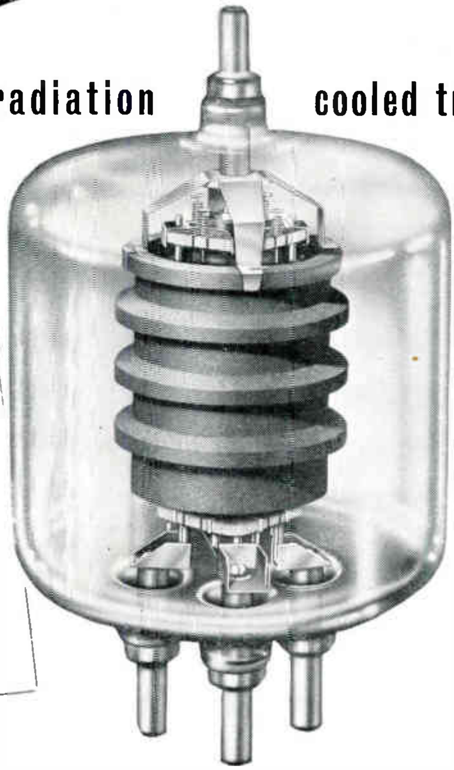

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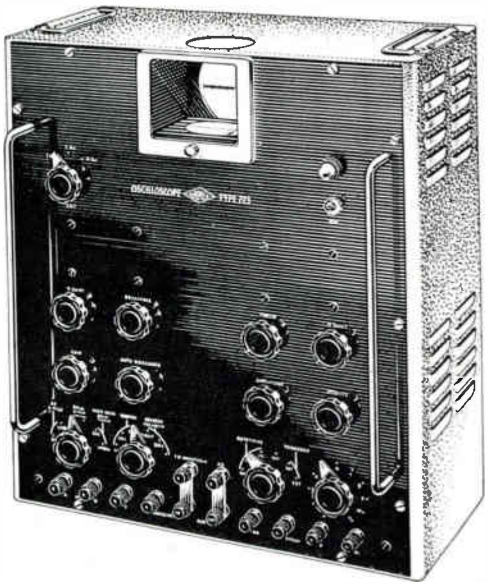

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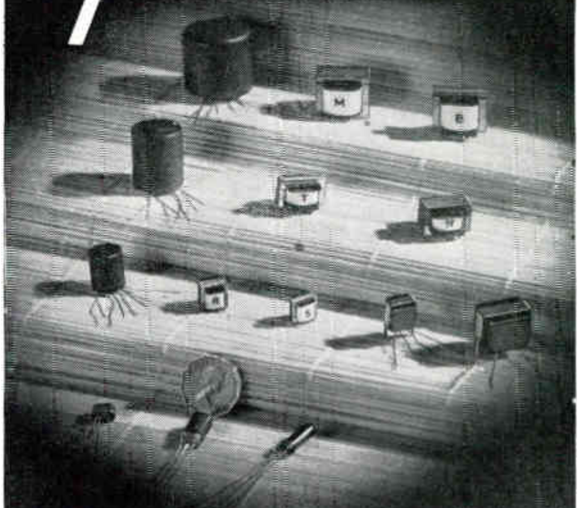

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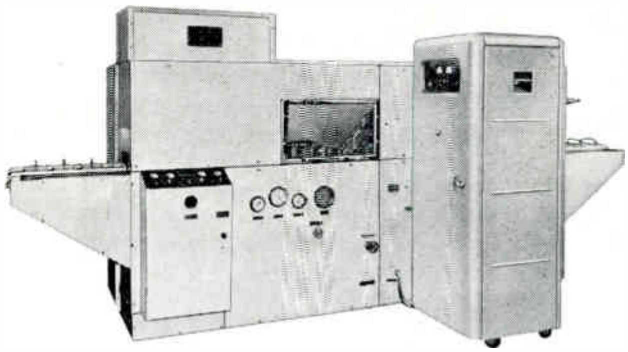

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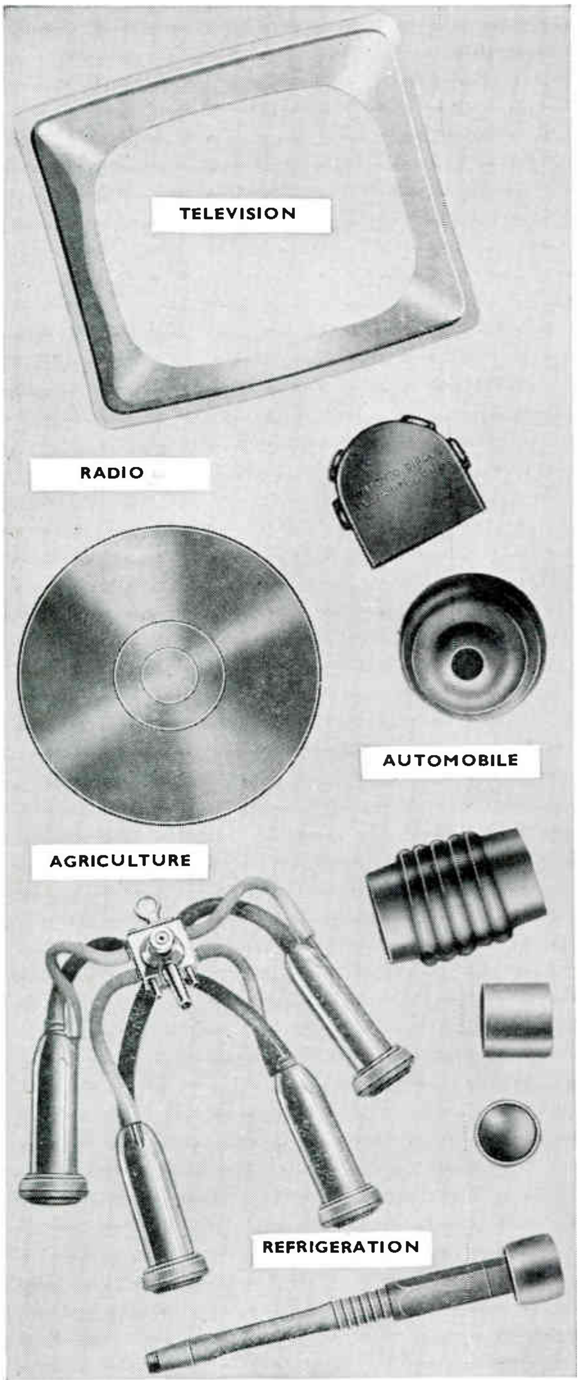


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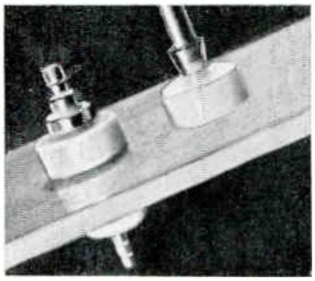

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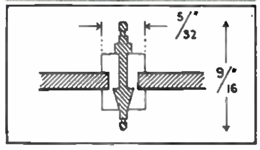


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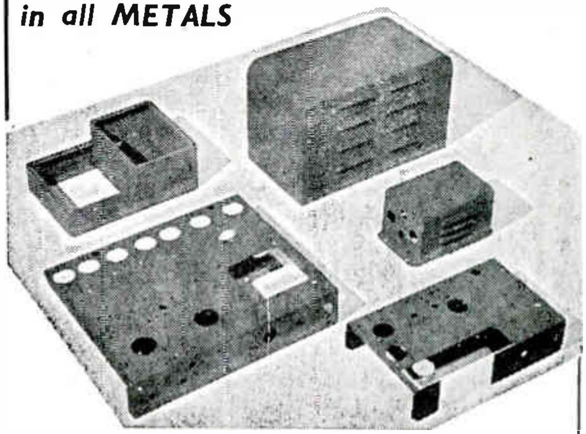

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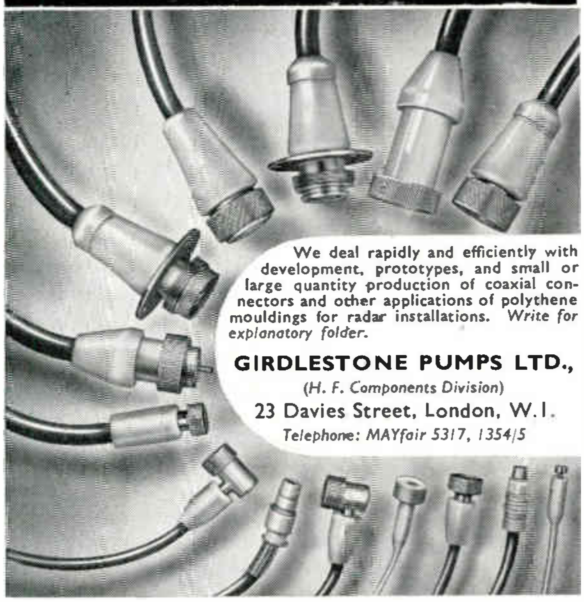

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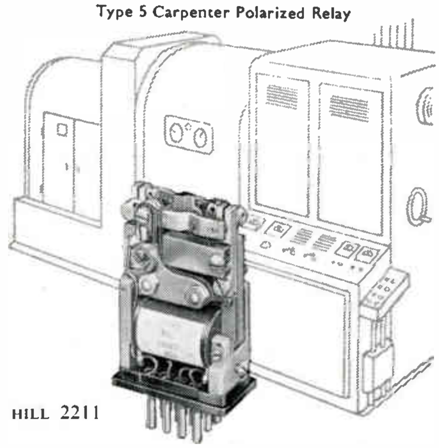

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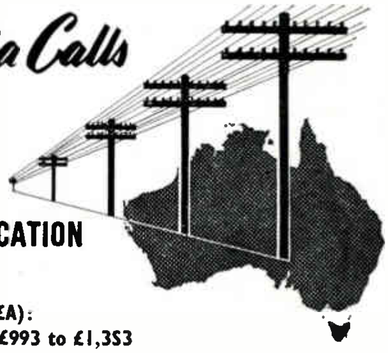

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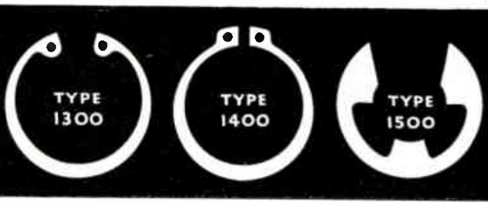


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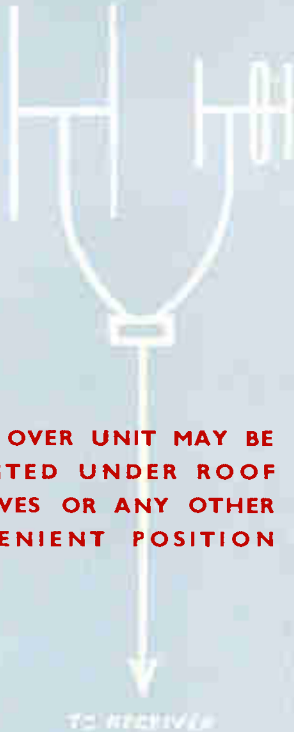


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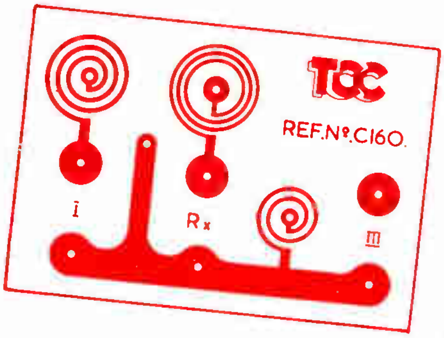


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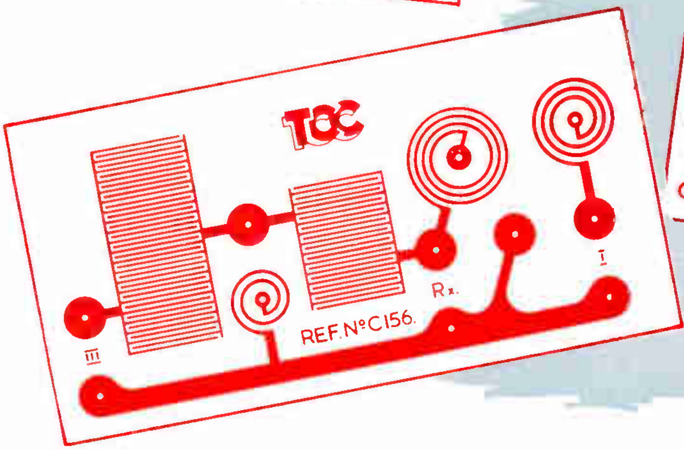


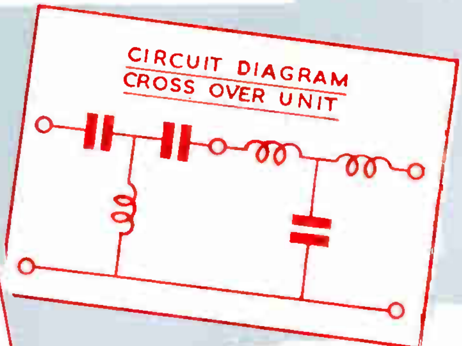


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